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Measuring the Sustainability of U.S. Public Bicycle Systems

A Thesis

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
requirements for the degree of

Master of Urban and Regional Planning

by

Max Whitman Williamson

B.S. Florida State University, 2008

December 2012

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GLOSSARY OF TERMS

BSS	Bicycle Share System
BTS	Bureau of Transportation Statistics
CaBi	Capital Bike Share
CMAQ	Congestion Mitigation and Air Quality Improvement Program
D-DOT	Washington, D.C. Department of Transportation
FHWA	Federal Highway Administration
GIS	Geographic Information Systems
GPS	Global Positioning System
IT	Information Technology
NGO	Non-Governmental Organization
NHTS	National Household Travel Survey
NMT	Non-Motorized Transportation
PABS	Pedestrian and Bicycle Survey
PBS	Public Bicycle System
PT	Public Transit
RFP	Request for Proposal
RFID	Radio Frequency Identification
RQ	Research Question
RTD	Regional Transportation District (Denver, CO)
TOD	Transit Oriented Development
TRID	Transportation Research International Documentation
US-DOT	United States Department of Transportation
VMT	Vehicle Miles Travelled

Abstract

As cities worldwide plan for increasing urbanization levels, new challenges in mobility will arise. Any approach taken to address these new issues will need to consider how to move more people with declining resources, thus the need for a sustainable solution arises. This thesis examines the growing trend of cities creating public bicycle systems as a means to add sustainability to a transportation system and identifies what are the criteria and indicators of a sustainable public bicycle. The criteria and indicators are used to examine data collection techniques of three Public Bicycle Systems in the United States: Capital Bikeshare in Washington, D.C., Nice Ride in Minneapolis, Minnesota and Denver B-Cycle in Denver, Colorado.

Keywords: Public Bicycles; Bike Share; Sustainability; Urban Transportation; Non-Motorized Transportation;

CHAPTER 1: INTRODUCTION

Cities all over the world are planning for increased levels of urbanization in the next fifty years and the new challenges to mobility a larger population will bring. Preparation techniques have ranged from widening roads to building new public transport systems. Of key importance to all these projects is creating a system that is sustainable, as populations grow and resources continue to decline. It should be noted that in this thesis the term “Sustainable Transportation” refers to a system that has a minimal dependency on fossil fuels, and negative impacts on the environment are few to none. Furthermore, sustainable transportation systems positively impact their area’s economic, social, and environmental issues, often referred to as the triple bottom line. With sustainability becoming an ever increasingly important concept in planning, it is necessary to separate the real benefits a new system can deliver from ideal outcomes.

As public bicycle systems like Paris’s famed Velib mature, cities all over the world are beginning to pursue a similar system of their own. Advocates claim these systems encourage short trips (<2 miles) by bicycle instead of car, increase public health, and decrease levels of air pollution. This thesis will focus on what data public bicycle system operators are gathering about the real impacts they have on the transportation system.

RESEARCH OBJECTIVE

The purpose of this thesis is to provide more research on public bicycle systems (also known as bike share systems, smart bikes, and public bike hire schemes) to help local governments and bicycle advocates determine what the actual sustainable benefits are to a transportation system. Such benefits would address all branches of the triple bottom line including, but not limited to, creating a more multi-modal system, equitable mobility offering equal access to all residents, reducing motor vehicle miles travelled, improving public health

and stimulating economic development. Moreover, this thesis seeks to answer whether or not public bicycle systems (PBS) are a sure method to create a more sustainable transportation system, one component of a larger reinvention of the transportation system, or offer no benefits to the sustainability of a system. It is an effort to look at what data is being collected, and what data needs be collected to understand what type of impact bicycle shares are having on mode shares. This thesis will also briefly examine issues regarding data collection of non-motorized transportation trips in other studies (i.e. the National Household Travel Survey).

RESEARCH QUESTIONS

RQ1: What are the criteria of a sustainable transportation system and key indicators of such criteria?

RQ1A: What are the criteria of a sustainable public bicycle system and key indicators of such criteria?

RQ2: What data is being collected on Public Bicycle Systems?

RQ2A: Is there a standard methodology systems are using to collect this data?

RQ2B: How have international public bicycle systems collected data?

RQ3: What does this data show about a public bicycle system's impacts on a city's overall transportation system?

RQ3A: Does the data show an impact on the types of trips being taken?

RQ3B: What modes are being replaced with the public bicycles?

RQ4: Does the data show an attempt to increase the social equity of a transportation system?

RQ4A: Does the resulting equity provide an increased level of access for all groups across socio-economic levels?

RQ5: What does data collected show about potential economic development a public bicycle system can offer?

RQ6: Does the data being collected support claims of health benefits (i.e. increased levels of personal activity and safety to users) from public bicycle systems?

METHODOLOGY

The methodology used to examine this thesis will be a mixture of literature review and original research using PBS in Denver, Colorado, Minneapolis, Minnesota, and Washington, D.C. as case studies. As public bicycle systems are still an emerging mode of transportation a research gap exists on impacts they have on a city, especially in regards to proving benefits. Because of this the literature review chapter undertakes a broad analysis of past research on the history of public bicycle systems, non-motorized transportation data collection, and measuring sustainability in transportation. This chapter will serve to answer some of the research questions; more specifically all of RQ2 as well as parts of RQ3, RQ4 and RQ5. The chapter following the literature review will answer RQ1 by identifying what are the key indicators of a sustainable transportation system. The indicators identified will be used again in the case study chapter.

The majority of the original research will be through reviewing public records and first hand interviews with the system operators and other key stakeholders in the cities of Denver, Colorado, Minneapolis, Minnesota, and Washington, D.C. The case study chapter will answer parts of RQ3, and all of RQ4, RQ5, and RQ6.

INTENDED OUTCOMES

This thesis focuses on data that confirms whether a public bicycle system's impact on a transportation system makes it more sustainable or are they simply the trendy thing for cities to do at the moment in cities around the world. There is little doubt that bicycles are a sustainable form of transportation, but do these same benefits come along with public bicycle systems and is there evidence of this happening?

This thesis is only a beginning contribution to the growing body of research examining the impacts this new mode of transportation can and is having on cities around the world. Regardless of whether or not data is found to support claims of sustainability, it is not the intention of this thesis to determine whether or not a particular system is sustainable, but merely point out flaws in attempts to quantify these claims.

Chapter 2: Literature Review

With Public Bicycle Systems being a relatively new and still emerging mode of transportation, there is a research deficit on their impacts. This literature review will examine the growing body of research on public bicycles as well as beyond this mode to discuss the broader body of research on all modes of non-motorized transportation (NMT). This chapter begins with an overview of the development of PBS and the data collection technology built into them offering the reader an introduction to these systems. Following that is a discussion on criteria for sustainability in transportation systems and methods of measuring indicators of such criteria. This discussion results in a list of indicators this thesis will use to evaluate existing public bicycle systems, which will serve to answer RQ1, RQ2A, and RQ2B. There is a brief analysis of the Public Bicycle System's of Hangzhou, China and Barcelona, Spain to answer RQ2B and RQ6, as well as contribute to RQ3. Finally this literature review looks at data collection methods for other modes of sustainable transportation, which will also help answer RQ2A.

OVERVIEW OF PUBLIC BICYCLE SYSTEMS

Although this thesis does not aim to give an extensive history of public bicycle systems, an understanding of their development and key concepts is important. The newest generation of public bicycles that have become popular on the streets of Europe and Asia today are known as the third generation of public bicycles (DeMaio, 2009; Midgley, 2011; New York City Department of City Planning, 2009; Shaheen, Guzman, & Zhang, 2010). The systems were first implemented in the 1960s on the streets of Amsterdam in a program known as 'Witte Fietsen' or White Bikes (DeMaio, 2004, Shaheen et al, 2010). This first generation of bicycle sharing had white bikes left around Amsterdam for anyone to use at their own will. This system failed from

high rates of theft and vandalism, leading to the second generation, which saw the addition of a coin deposit mechanism as a means to reduce theft (DeMaio, 2004, Shaheen et al, 2010).

The current generation of PBS (the 3rd generation) builds upon the previous incarnations, but takes advantage of major developments in information technology (IT), which has led generation of systems to be referred to as smart bicycles (DeMaio, 2004). This new technology provides an abundant new source of data, which is discussed later in this chapter. This style of system debuted in Lyon, France in 2005, while the first major city to implement such a PBS was Paris, France whose Velib system premiered in 2007 and saw its 100 millionth trip in summer 2011 (DeMaio, 2012a, 2012b; Intelligent Energy in Europe, 2011).

As more cities begin to develop PBS, a fourth generation has begun to emerge. This system builds upon the IT of the third generation, but is executed in a “Demand Responsive Multi-Modal System” as (Shaheen et al., 2010, 165). These systems are intended to provide a greater level of sustainability and more efficiently cater to a users mobility needs through steps such as offering a single access card that allows better public transit integration (Shaheen et al., 2010). Some fourth generation systems also feature pedal assist/electric bicycles (DeMaio, 2009).

The two French systems mentioned above are examples of a larger trend in European PBS using outdoor advertising firms serve as system operators (i.e. Clear Channel, JCDeaux, etc.). Of the five primary public bicycle operation models identified through research of this thesis, (advertising firm, public transit agency, bike share company, non-profit organization or local government) the advertising option has seen least development in the United States (DeMaio, 2012a; IEE, 2011; Midgley, 2011). Washington, D.C. did launch a PBS partnership with the advertising firm Clear Channel, using their SmartBike system, After public demand for the system outgrew its capacity, the District Department of Transportation (D-DOT) redeveloped

the system on a regional scale with Arlington, Virginia, opting for a program operated by a bike share company (Lisle, 2011; Moskowitz, 2011, 2012).

The most fitting role for public bicycles to play in an urban transport system is connecting modes in a multi-segment trip and fulfilling short distance trips (Shaheen et al., 2010). One method to encourage these types of trips is through the system's pricing scheme. Most systems offer users multiple subscription levels to access the bikes as either a casual user (single day, 7 day pass) or a more frequent user (6 months, annual membership). Systems around the world typically begin with a free period (i.e. first 30 minutes) after this time the price begins to increase progressively before ultimately reaching a maximum daily charge or a fine (IEE, 2011; Midgley, 2011; NYC, 2009). This pricing structure essentially offers annual and monthly members a mode of transportation cheaper than private automobile and even public transit, if they take trips within this 30-minute window (IEE, 2011). This pricing structure also ensures that public bicycles are not viewed as a rental bike that a tourist may use to sightsee.

While the 2009 National Household Travel Survey (NHTS) doesn't show a significant increase in the share of bicycling trips (relative to all trips of all modes) over the 2001 survey, it does show more walking trips (Pucher, Buehler, Merom, & Bauman, 2011). This finding shows promise to developing public bicycle systems. If people are choosing to walk instead of cycle these short distance trips, this suggests there could be some negative component bicycling would add to these trips (i.e. having to find bike parking, unable to change modes if the weather were to change, etc.). A PBS can offer the same benefits' walking has over traditional cycling (the ability to make this type of trip anytime without special equipment, i.e. owning a bicycle) while also offering the range a bicycle has over walking.

When inspecting the data on cycling trips more clearly, the NHTS shows an increase in bicycle trips for all purposes except for recreation between 2001 and 2009 (Pucher et al., 2011;

Oak Ridge National Laboratory, 2005; USDOT, 2010a). Furthermore cities that have made substantial investments to their bicycling infrastructure have seen a steady increase in utilitarian bicycle trips (Pucher and Buehler, 2011; Pucher et al., 2011; Swanson, 2012). These findings suggest there is a niche, which public bicycles can fill in U.S. cities if they are properly developed.

SUSTAINABLE TRANSPORTATION SYSTEMS

As sustainability is a rather ambiguous concept, it is important to clearly define the scope through which sustainability is being examined for this research (Gudmundsson, 2003). Because of varying interpretations of the concept, one may view a transportation system sustainable, while someone else may not. Although there is still an ongoing discussion as to what criteria must be met to identify a system as sustainable, the consensus is that existing modes (i.e. private automobiles) are unsustainable (Gudmundsson, 2003). One of the most commonly accepted international definitions of the concept comes from the United Nations Brundtland Commission: “Meeting the needs of the present generation without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987). For the purposes of this thesis, analysis will build off this definition taking into account economic, social and environmental factors, commonly referred to as the triple bottom line (Amekudzi, Meyer, Ross & Barrella, 2011; Beatley, 1995; Litman, 2007).

It should also be noted that this thesis does not interpret sustainability as a threshold, where something is absolutely sustainable, or absolutely not sustainable, but rather a sustainable pendulum where systems are more or less sustainable than others. A PBS which encourages shifting away from conventional transportation modes, and helps residents achieve increased activity, but relies on grants to cover operating costs, should not be labeled, “unsustainable,” it is simply less sustainable than a system that provides the first two benefits and uses its own revenue for all operating costs.

Criteria define crucial components of a sustainable transportation system. In order to identify these criteria, indicators, which correlate with a particular criterion, are used (Gudmundsson, 2003). Indicators (used for analysis in many disciplines) are variables used to show the impact a system is having toward an objective (Litman, 2007). Representing a paradigm shift within transportation planning, sustainability indicators are different from those used to measure criteria of conventional modes (Litman, 2007, 2011; Zietsman, Ramani, Potter, Reeder, & Defloria, 2011).

With so few PBS currently in operation in the United States, there is yet to be a standardized data collection technique across jurisdictions and no guarantee whether other systems are even collecting data. As more systems develop across the U.S., a common set of indicators and standardization of methods in collecting data on such indicators should begin to present themselves. The lack of longitudinal data on U.S. public bicycles will also impede any analysis of long-term trends in the sustainability of systems (Litman, 2007). Litman (2007) identifies goals, objectives, and performance measures of sustainable transportation systems through economic, social and environmental aspects. He goes on to rank them by their importance and how often they should be used as well as highlight indicators that can be used to examine specific goals, see Table 1 (Litman, 2007). Measuring vehicle miles travelled (VMT) is one such indicator that may be always used. It should be noted that although a reduction in VMT is desirable for sustainability, a reduction by itself does not automatically translate in sustainability as this does not consider economic benefits that motor vehicles may provide to individuals (i.e. resident lives in an area where there is no public transit and therefore must rely on private automobile) (Litman, 2007). Using VMT in analysis of public bicycles however is one of the situations in which a reduction in VMT would certainly indicate characteristics of sustainability, as long as this reduction is a result of mode replacement (Litman, 2007).

Table 5: Recommended Sustainable Transportation Indicators

	Economic	Social	Environmental
Most important (should usually be used)	Per capita mobility (daily or annual person-miles or trips) Mode split (personal travel: nonmotorized, automobile and public transport; freight: truck, rail, ship and air) Average commute travel time and reliability Average freight transport speed and reliability Per capita congestion costs Total per capita transport expenditures (vehicles, parking, roads and transit services)	Per capita traffic crashes and fatalities Quality of transport for disadvantaged people (disabled, low incomes, children, etc.) Affordability (portion of household budgets devoted to transport) Overall satisfaction rating of transport system (based on objective user surveys) Universal design (consideration of disabled people's needs in transport planning)	Per capita energy consumption, disaggregated by mode Energy consumption per freight ton mile Per capita air pollution emissions (various types), disaggregated by mode Per capita land devoted to transport facilities (roads, parking, ports, and airports) Air and noise pollution exposure and health damages Impervious surface coverage and stormwater management practices
Helpful (should be used if possible)	Relative quality (availability, speed, reliability, safety, and prestige) of non-automobile modes (walking, cycling, ridesharing, and public transit) relative to automobile travel Number of public services within 10-min walk and job opportunities within 30-min commute of residents	Portion of residents who walk or bicycle sufficiently for health (15 min or more daily) Portion of children walking or cycling to school Community cohesion (quality of interactions among neighbors) Degree cultural resources are considered in transport planning	Community livability ratings Water pollution emissions Habitat preservation Use of renewable fuels Transport facility resource efficiency (such as use of renewable materials and energy-efficient lighting)
Specialized (use to address particular needs or objectives)	Portion of households with Internet access Change in property values	Transit affordability Housing affordability in accessible locations	Impacts on special habitats and environmental resources Heat island effects
Planning process	Comprehensive (takes into account all significant impacts, using best current evaluation practices) Inclusive (substantial involvement of affected people, with special efforts to ensure that disadvantaged and vulnerable groups are involved) Based on accessibility rather than mobility Application of smart growth land use policies		
Market efficiency	Portion of total transportation costs that are efficiently priced Neutrality (public policies do not arbitrarily favor a particular mode or group) in transport pricing, taxes, planning, investment, etc.; applies least-cost planning		

NOTE: This table identifies various sustainable transport indicators ranked by importance and type. For equity analysis, indicators can be disaggregated by demographic factors, so impacts on disadvantaged groups (people with disabilities, low incomes, children, etc.) are compared with overall averages.

Source: Litman, 2007

The National Cooperative Highway Research Program identifies 11 key goals of sustainability for transportation agencies, as identified in Table 2 (Zietsman, Ramani, Potter, Reeder & Defloria, 2011).

As discussed earlier, bicycles and other modes of non-motorized transportation meet many of the goals of a sustainable transportation system, which has led to much of this data being applied anecdotally to PBS (Bassett, Pucher, Buehler, Thompson, & Crouter, 2008; Bikes Belong, 2011; Gotschi & Mills, 2008; Handy, 2009; Ogilvie, Egan, Hamilton, Petticrew, 2004; Pucher & Buehler, 2010; Pucher et al., 2010a). Additionally, studies have shown major environmental, and public health benefits from increased levels of walking and bicycling (Gotschi & Mills, 2008). The U.S. Department of Health and Human Services recommends

adults get 2 hours and 30 minutes of moderate physical activity a week to prevent obesity and reduce the risk of heart disease and other non-communicable diseases (Handy, 2009). Using active transport (such as walking) to commute for 15 minutes, twice a day can provide these recommended levels of physical activity (Handy, 2009). Despite this small amount of time required to achieve these benefits, 2007 saw less than half of the U.S. population perform this level of physical activity, 13.5% of which received zero physical activity (Centers for Disease Control and Prevention, 2008).

A system that does not provide safety to its users certainly cannot be considered sustainable and a lack of safety measures (perceived or real) is a major reason many individuals do not use non-motorized transportation (Handy, 2009; McClintock, 2002; Tolley, 2003). In fact, one of the most compelling reasons to invest in facilities to which will improve a non-motorized transportation user's experience (such as bike lanes or pedestrian boulevards) is the proven impact it has on the general safety for cyclists and pedestrians and usage rates (Gehl, 2010; Jacobsen, 2003; Pucher & Buehler, 2010; Pucher et al. 2010). This concept, which has come to be known as "safety in numbers" suggests that as cycling and walking rates increase, the number of fatalities and injuries resulting incidents between motor vehicles and non-motorized transportation decreases (Jacobsen, 2003; Pucher & Buehler, 2010).

Analyzing collision rates between motor vehicles and walking or cycling, researchers found a negative relationship between the number of collisions and non-motorized transportation rates across various European and American cities in different time periods. The likelihood of a pedestrian being hit by a motor vehicle in an area that has increased walking rates by 50%, is reduced by 66% (Jacobsen, 2003). These results suggest a type of behavior modification of motor vehicle drivers as non-motorized transportation increases for a few reasons. Drivers will be more familiar with looking for non-motorized transportation users as well as greater knowledge of how to share the road with these more vulnerable modes. Also, there

will be a greater percentage of drivers who themselves use non-motorized transportation, and therefore more responsive to these groups (Pucher and Buehler, 2010).

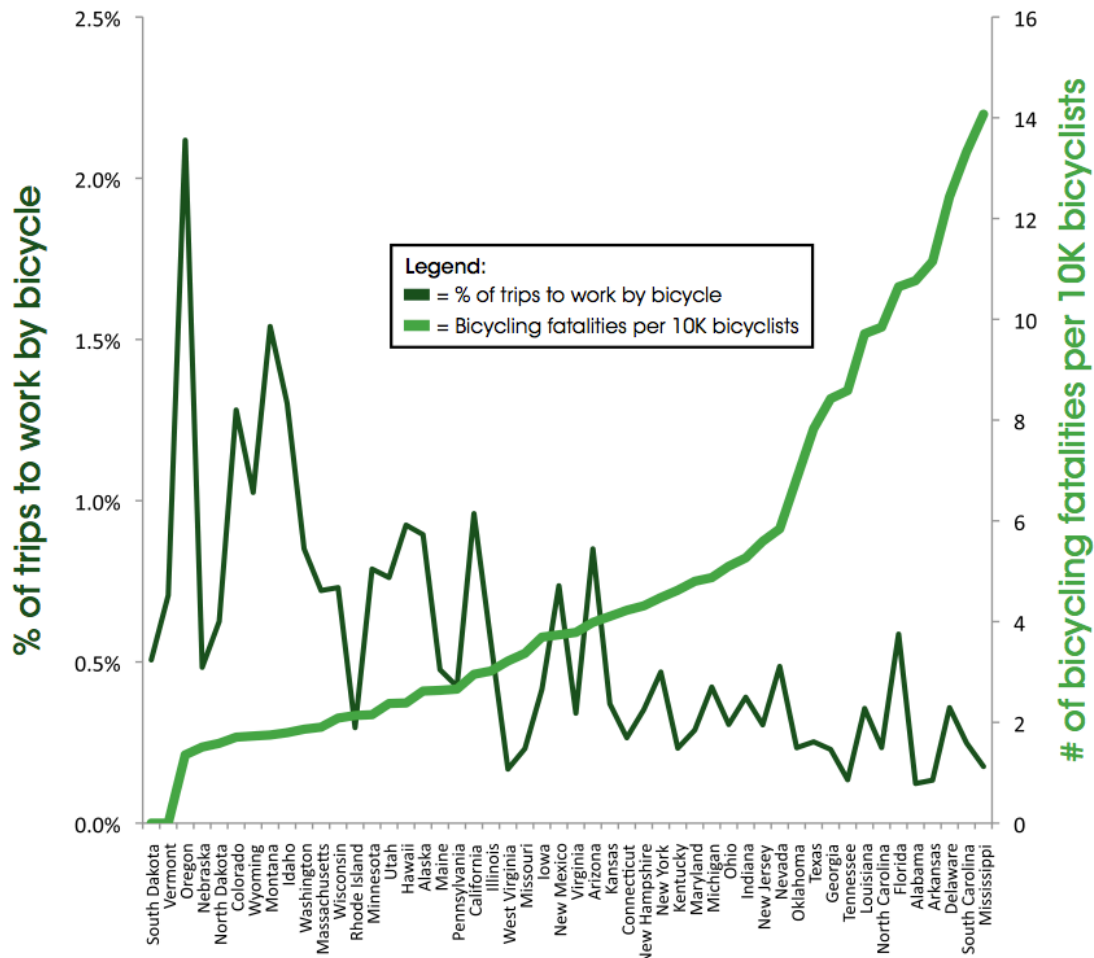
Table 6: Goals of a Sustainable Transportation System

Goal	Definition
Safety	Provide a safe transportation system for users and the general public.
Basic Accessibility	Provide a transportation system that offers accessibility that allows people to fulfill at least their basic needs.
Equity/Equal Mobility	Provide options that allow affordable and equitable transportation opportunities for all sections of society.
System Efficiency	Ensure that the transportation system's functionality and efficiency are maintained and enhanced
Security	Ensure that the transportation system is secure from, ready for, and resilient to threats from all hazards.
Prosperity	Ensure that the transportation system's development and operation support economic development and prosperity.
Economic Viability	Ensure the economic feasibility of transportation investments over time.
Ecosystems	Protect and enhance environmental and ecological systems while developing and operating transportation systems.
Waste Generation	Reduce waste generated by transportation-related activities.
Resource Consumption	Reduce the use of nonrenewable resources and promote the use of renewable replacements.
Emissions and Air Quality	Reduce transportation-related emissions of air pollutants and greenhouse gases.

Source: Zietsman et al., 2011

The Alliance for Biking and Walking analyzed the 2009 American Community Survey (ACS) data on bicycle commuter mode share and the National Highway Traffic Safety Administration's (NHTSA) Fatality Analysis Reporting System's (FARS) three year average of bicycle fatalities, see Figure 1 (Swanson, 2012). What they found was a negative correlation between the percent of trips to work by bicycle and the number of bicycling fatalities per 10,000 bicyclists, which suggests the more steps a city takes to encourage cycling, the greater decline they will see in cyclist fatalities (Steele and Altmaier, 2010; Swanson, 2012).

Figure 9: Relationship Between Bicycling Levels and Bicycling Related Fatalities in United States



Source: Swanson, 2012

The level of integration between any particular mode and a region's transportation system can determine how sustainable the system is. Providing designated bike routes to transit hubs and secure parking at rail stations has been seen to improve usage of both modes (Martens, 2004, 2007; Pucher and Buehler, 2010; Pucher et al., 2010). By integrating bicycles with a rail system, vehicle miles travelled can be reduced greatly while allowing users the option to increase the range of a potential trip over either of the two modes on their own (Bachand-

Marleau, Larsen, & El-Gene, 2010). Regarding specific benefits of PBS-transit integrations, a system can connect the “first and last mile,” the trip from origin to transit and then transit to destination (Bachand-Marleau et al., 2010). Existing research on integration between PBS and transit has not shown a strong trend yet. The Dutch OV-Fiets system has seen strong usage due in large parts to its integration with rail stations (Martens, 2007). Examining the first large scale North American PBS, Montreal, Canada’s *BIXI*, one sees results more similar to the Hangzhou, China case study mentioned above with many PBS trips replacing public transit or walking (Bachand-Marleau et al., 2010). This same study showed that among BIXI subscribers, a majority makes intermodal PBS-transit trips.

STATUS OF RESEARCH ON PUBLIC BICYCLE SYSTEMS

As stated above, the body of research on public bicycle systems is constantly growing, however data, which specifically quantifies their impacts, is lacking (Pucher, Buehler, Bassett, & Dannenberg, 2010a; Shaheen, Zhang, Martin, & Guzman, 2011). Performing a search for the phrase “bicycle sharing” on the Transportation Research Board’s Transportation Research Information Database (TRID), one gets a good idea of this knowledge gap. This query only provides 72 results of studies and articles examining public bicycles, close to a third of these were from 2012 alone¹. Much of the data that is available comes from grey literature, non-academic professional papers.

Despite this lack of proven results, there is no shortage of claims of the benefits these systems can provide. Many of the claims of benefits a public bicycle system can provide appear to be based on anecdotal evidence and logic: bicycles are sustainable so a citywide system of bicycles will be even more sustainable. Other claims use successes these systems have seen in Europe to suggest they will provide similar results in the United States. One example of these

¹ Search performed by author on September 24, 2012.

types of claims is seen on the website of the non-profit bicycle advocacy organization, Bikes

Belong:

Bike sharing is good for cities in many ways. It delivers all the benefits of bicycling: by replacing car trips, it helps the environment, road congestion, the economy, parking, mobility, and traffic safety. In addition, bike sharing has unique advantages. It is more convenient and affordable than bike ownership for many residents; it helps overcome barriers to using a bike in a city, such as theft and storage; it generates revenue for municipalities and private companies; it creates new jobs; it motivates cities to improve bike infrastructure; it both connects to and relieves pressure on transit; it provides branding for a city; and it introduces new audiences to bicycling (Bikes Belong, 2011).

Although this same website does provide case studies, most of the empirical data within them comes from European systems. The difference in perceptions of bicycles between Europe and the United States, coupled with varying land use policies, suggest that international success may not be the best indicator of similar outcomes domestically. However, this thesis does provide some analysis of data collected on international systems as the vast majority of PBS lie outside of the U.S. (DeMaio, 2012b).

INTERNATIONAL EXAMPLES

This section provides analysis of sustainable indicators collected on international public bicycle systems. The first examines a major urbanized city with the largest PBS in the world, as of Fall 2011² (DeMaio, 2012b). The second is one of the best and most frequently cited studies examining environmental and social indicators.

HANGZHOU

Hangzhou is located in China's east coast province of Zhejiang with a population of 6.78 million (Shaheen et al., 2011). Their PBS is one of the largest and most dense systems in the world with over 60,000 bikes in 2,400 stations with the ultimate goal of 175,000 bikes by 2020 and is operated by the Hangzhou Public Bicycle Transport Service Development Co. Ltd., a

² Hangzhou has since lost this title to Wuhan China.

subsidiary of the city's public transit authority (DeMaio, 2012b; Shaheen et al., 2011). Launched in 2008, the system was meant to help with increasing congestion levels on roads as well as the city's buses. Hangzhou is unique from most North American cases for two reasons: it was launched with specific steps to integrate with the public transit system and the city itself has a historically high level of bicycling (Shaheen et al., 2010, 2011).

As a method to help alleviate public transit congestion, the system involves a smart card that serves as both the access key to the bicycles as well as a transit pass (Shaheen et al., 2011). This multi-purpose pass allows for seamless transitions between modes and a reduced fare when a transfer is made between the city's bus rapid transit service and the PBS (Shaheen et al., 2011).

In 2010, Shaheen, Zhang, Martin and Guzman conducted an intercept survey of members and non-members to understand the factors leading to or discouraging residents from becoming users in the system's first two years of service. This study did not focus on the social or economic indicators of a sustainable system, but rather environmental indicators associated with a change in travel behavior.

From the 806 respondents, the survey showed the PBS is having a major impact on the transportation system and meeting its initial goals (Shaheen et al., 2011). Of the respondents who own a car, 78% said they are using the system to replace trips that would have been made by a private automobile (Shaheen et al., 2011). Although many bike sharing trips were reported as replacing the sustainable modes of walking and public transit, this shift suggests that buses will be less crowded offering commuters who were previously deterred, to now access the system (Shaheen et al., 2011).

BARCELONA

The story of public bicycles in Barcelona is much different than Hangzhou. Where as China had a historically high mode share of bicycles, Spain does not. Before the launch of

Barcelona's Bicing, bicycles accounted for 0.75% of trips in the city, the year the PBS was launched, that number rose to 1.76% (Romero, 2008). The system operator model is also different. Barcelona contracts the service out to the outdoor advertising firm Clear Channel.

Bicing is also unique among European systems. Launched the same year as the Paris Velib system (2007) Barcelona's PBS is not open to tourists, but exclusive to residents of the city (IEE, 2011; Rojas-Rueda, de Nazelle, Tainio, Mark, & Nieuwenhuijsen, 2011). This was one step Barcelona took to ensure they did not over build their system and to prevent competition with existing bicycle rental systems. In addition they limited the number of memberships offered until more bicycles were put into service (IEE, 2011).

Unlike the above-mentioned Hangzhou study, which made no attempt to quantify environmental or social benefits, a study in Barcelona aims to do just this by looking at the health benefits and carbon reduction a system provides (Rojas-Rueda et al., 2011). Moreover this study not only examined public bicycles, but provided risk-benefit analysis of traditional urban bicycle riding as well (Rojas-Rueda et al., 2011). Measuring all cause mortality from physical activity, air pollution and road traffic accidents, the authors were able to prove that health benefits provided by urban cycling outweigh the risks and public bicycles can serve as a method to reach these positive results (Rojas-Rueda et al., 2011).

Although the system is open to all residents of Barcelona, this study looked at the 11% (182,062) of the city's population (1.6 million) who had subscribed to the system in its first two years of service (Rojas-Rueda et al., 2011). Researchers examined those cyclists in Barcelona who began regularly cycling after Bicing came into service. The researchers concluded that by replacing car trips with Bicing the cities expected death toll from traffic related accidents and air pollution would increase by 0.03 and 0.13 deaths annually, respectively (Rojas-Rueda et al.,

2011). However the increased active transport provided by the PBS would reduce the number of the cities expected annual death toll by an estimated 12.46 (Rojas-Rueda et al., 2011).

These results clearly show there can in fact be public health benefits from PBS. The methodology employed in this study is easily repeatable showing that this can be applied to PBS systems around the world to measure their impact and give programs the evidence to show public health benefits. These findings based on a real world system complement a recent study based on a hypothetical mode replacement scenario. By assuming 500,000, 18-64 year olds replaced short trips (defined as 7km and 15kms, in two different models) made by car with bicycle, air pollution exposure and potential traffic crashes would decrease their lifespan between 0.8-40 days and 5-9 days (respectively), but see a benefit of 3-14 months gain in expected lifetime (de Hartog, Boogaard, Nijland & Hoek, 2010).

The Barcelona case study has very promising findings for other cities that wish to develop a public bicycle system. For one, this study was undertaken with data from just over two years of service suggesting that benefits could be greater the longer a program is around and user rates increase. While the system looked at the 11% of Barcelona's total population that had registered as a user, Rojas-Rueda and others (2011) calculate that closer to 1% of the total population actually use the system on a regular basis. What's more, the increased risk from inhaling emissions will be reduced as more residents switch to the system and there are fewer cars on the road producing such emissions.

Looking beyond the scope of this study to other indicators of a sustainable PBS, Bicing appears to be increasing the sustainability of their transportation system. With the system only available to residents, its purpose is to increase mobility options to residents across the city (Midgley, 2011). While Barcelona may not offer seamless transfers between public transit and Bicing, wayfinding signage exists throughout the Barcelona subway to direct travelers toward

the PBS system and better integration between the PBS and public transit (PT) to aid in regional multi-modal, non-automobile trips is one of the city's goals (IEE, 2011; Midgley, 2011). Also the increase in the bicycle mode share since the program's launch shows a shift to more sustainable modes across all residents, not just Bicing members.

DATA COLLECTION OF NON-MOTORIZED TRANSPORTATION

The paradigm shift within the transportation-planning field, that is sustainability, means the sharing of best practices is critical to identifying what does and doesn't work. Similarly the data collection process must start before the implementation of a new approach and continue through its operation to gather longitudinal data; by agreeing on a standard data collection process uniform gathering of longitudinal data will be ensured (Pucher et al., 2010).

To overcome the lack of data on public bicycle systems, this thesis examines the state of data collection for other non-motorized transportation modes. Getting an accurate count of bicyclists or pedestrians is typically more costly and labor intensive than measuring private automobiles and many trips go uncounted resulting in irregularities in comparing across jurisdictions (Barnes & Krizek, 2005; Jacobsen, 2003; Krizek, 2006). In the above-mentioned article regarding "safety in numbers", Jacobsen provides an extensive discussion on potential shortcoming of his findings based on different methods of data collection across time and geographies (2003). There are also difficulties in singling out increased number of cyclists from PBS versus other interventions (discussed in greater detail below). Therefore this thesis examines methods to measure benefits of both bicycle facilities as well as bicycles themselves (Pucher et al., 2010).

The existing gap in data required for NMT planning has been realized for some time (USDOT, 2000, 2010b). One of the greatest voids is related to the "number of bicyclists and pedestrians by facility or geographic area," which the Bureau of Transportation Statistics (BTS)

rates as poor existing data and a high priority to gather such data (USDOT, 2000, 3). Measuring the number of cyclists alone is not an adequate method to evaluate a system. To coincide ensure non-motorized transport systems are monitoring safety for users, collection of crashes in a uniform methodology across jurisdictions is a major shortfall in existing non-motorized transport planning (USDOT, 2000).

An analysis of pedestrian and bicycle data collection across 29 different agencies shows there is not a one size fits all approach. Rather different agencies have different data requirements and resources available (Schneider et al., 2005). The authors found that collecting data on where and what type of NMT trips are occurring, existing NMT facilities, what impact facilities have on trips, and how safe an area is for NMT leads to better success in integrating NMT into a multi-modal system. A major impediment for many communities is the collection of this data is expensive and time consuming. The Pedestrian and Bicycle Survey (PABS) is less expensive option for local communities to analyze their NMT systems (Forsyth, Krizek, & Agrawal, 2010). This method was developed to specifically meet known data gaps and ensure cities are collecting basic longitudinal data for bicyclists and pedestrians that would be necessary to carry out more invasive studies, such as incorporating information technology, as discussed below in greater detail (Forsyth et al., 2010).

Some advocates have suggested that NMT data collection can actually be more harmful to promoting sustainable transportation than it can to benefit it (Schneider, Patten, & Toole, 2005). If data collection shows low numbers of NMT users, policy makers could interpret the data as a justification to cut funding to these modes and instead further invest in less sustainable modes (Schneider et al., 2005).

The case studies Schneider et al. (2005) examined found most data collection to be focused on travel patterns and less attention was paid to the actual impact systems have on

economic or social variables. Looking beyond simple user counts and instead focusing on user perspectives can identify major shortcomings of a system. Travel behavior surveys such as the NHTS (or more specifically to NMT) the National Survey of Pedestrian and Bicyclist Attitudes can provide a PBS operator valuable data about why people choose a certain route, what they would like to see in a system and socio-economic factors which must be considered in providing an equitable system (Pucher et al., 2011; Pucher & Renne, 2003; Royal & Miller-Steiger, 2008; USDOT, 2010b). Through this data it can be seen many lower income residents in the United States have become trapped in a non-sustainable transportation system in which they are reliant upon automobiles instead of lower cost public transit and non-motorized transport (Pucher & Renne, 2003; Pucher et al., 2011).

One of the most comprehensive datasets on urban non-motorized transportation in the United States is the Alliance for Biking and Walking's Benchmarking Report, the most recent edition of which was released in January 2012. Their Benchmarking Report looks at data relating to bicycling and walking including usage rates, safety, policies, funding to these modes, and economic and public health benefits (Swanson, 2012). Data reported in the Benchmark covers the top 50 largest cities in the United States and New Orleans, using existing databases as well as original research collected from state and local governments, transportation agencies and metropolitan planning organizations as well as local advocacy groups (Swanson, 2012).

Looking at the direct impacts PBS have had on transportation systems in both the U.S. and European cities can be difficult as these systems are typically introduced with general improvements to their bicycling and walking networks (Pucher et al., 2010). While most of these cities have seen cycling rates increase, current data collection techniques can be problematic to single out what effect the PBS has had on these numbers and what increase has occurred as a result of measures (i.e. a protected bike lane) constructed at the same time (Pucher et al., 2010).

The stations where a user picks up or returns a public bicycle give the systems a much greater physical presence than traditional urban cycling. As a system grows it will increase the number of stations and their density, it is still beneficial to analyze the location of a station similar to the way one would analyze a bike lane or trail. Both facilities offer benefits to the users and thus the proximity one lives from them and ease of access will determine the level of use a facility will see (Krizek, 2006).

Although respondent bias can present itself in any kind of transportation user survey, measuring how likely a resident is to use a specific facility greatly depends on their belief as in what kind of facilities are the safest. In a study where residents were shown images of different on and off-street bicycle facilities, researchers measured what facilities cyclists in Minneapolis-St. Paul, Minnesota region prefer (Krizek, 2006). They found cyclists greatly prefer off-street, bicycling facilities as opposed to bike lanes or shared lanes in traffic because of a perceived greater level of safety (Krizek, 2006). Respondents claim to be willing to make a further distance trip, if it means using accessing these facilities (Krizek, 2006).

Another bias of survey respondents present in the existing literature, which PBS stations are able to nullify is quality of facilities (Krizek, 2006). When choosing a route or destination for a cycling trip, traditional cyclists may go with the most secure racks but PBS offer a fleet of uniform bicycles and a secure station, both of which see regular maintenance, essentially making this bias non-existent in PBS surveys.

Conducting revealed preference surveys also has the ability to remove some respondent biases. Krizek (2006) analyzed property values and residential proximity to both on and off-street cycle facilities in the Twin-Cities region. Residents living in the more urban areas preferred to live closer to off-street bicycle facilities than residents who in suburban neighborhoods (Krizek, 2006). Proximity to off-street facilities also increases the value of a

median priced home whereas in the suburbs it does the opposite (Krizek, 2006). It should be noted that this study finds on-street bicycle facilities have the opposite effect of those off-street, although the author says this could be because they are predominately located in less desirable neighborhoods.

Royal and Miller-Steiger (2008) also presented results that highlight an underserved group for whom a public bicycle system would benefit. The study found 26% of respondents, who did not ride a bicycle in the three-month study period (May-August 2002), lacked access to one, suggesting that a public bicycle system open to residents and visitors alike would offer greater mobility. Of those surveyed, the two lowest income quintiles (<\$15,000 and \$15,000-\$29,000) responded as having the lowest with access to a bicycle (Royal & Miller-Steiger, 2008). Although the question remains whether or not these groups would ride if were they provided access through a PBS, revealed preference survey discussed elsewhere in this thesis have shown that developing facilities will increase ridership (Dill & Carr, 2003; Jacobsen, 2003; Pucher et al., 2010). A longitudinal study examining the impact other types of facilities introduced in Minneapolis has on mode share of bicycle commuters appears to support this theory also (Barnes and Krizek, 2005).

A clear indicator of the impact new technology has had on research, just over a decade ago the BTS suggested the rise of information technology will be a major source of data used to explain NMT trends (BTS, 2000). Today, third generation public bicycles take full advantage of this huge source of data, with many systems offering this as open source, real-time data to the public (O'Brien, 2012). This has given smaller cities a more affordable method of forecasting bicycle travel demand, a process that can be costly and time consuming (Schneider et al., 2005).

With the data provided by information technology, system operators are able to examine the origin-destination of every trip, the route taken, the speed, and how often a member uses a bicycle. Also, with the requirement of each member to have a unique access card, PBS operators could ask him or her to confidentially share socio-demographic characteristics as a means to better identify who is using the system and the impacts it has on the community.

Although some PBS systems track the bicycles only through Radio Frequency Identifying (RFID) chips that register at the station they are checked out from and returned to, many are integrating GPS devices into the bikes (B-Cycle, 2011). GPS has already been used as an added data collector to traditional travel diaries (Forsyth et al., 2010; Stopher, Fitzgerald, & Zhang, 2008; Stopher & Speisser, 2011). While this source is typically unavailable to researchers due to privacy concerns, the presence of GPS receivers in many mobile phones could provide this extra data to systems that do not have it built in (Stopher & Speisser, 2011).

The integration of GPS into survey methods can also help eliminate multiple biases found in previous studies. The information technology allows for a more accurate level of data about cyclist route choices, whereas before they were predominately based on cyclist stated preference surveys (Krizek, 2006). If they are installed on every bicycle in a PBS, there is less of a risk that the data is coming from an individual who has self selected themselves for this survey, thus getting a picture of the general public.

Furthermore, as the fourth generation of PBS grows, travelers will have one smartcard they will use to access the bicycles and public transit. This will offer a dataset showing every transfer between public transit and bicycle and as well as how intermodal a transportation system is (Shaheen et al., 2010).

The information technology in public bicycle systems should not be the only means of data collection, but instead should be used in conjunction with traditional stated preference

surveys, just as PABS suggests using GPS to confirm trends that may have revealed themselves through surveys (Forsyth et al., 2010).

Aside from the greater levels of data collection provided by the information technology, when registering as a PBS member, users are required to provide personal contact information. This offers system operators a method by which to directly contact all system users to administer stated preference surveys. Although response rates may be the same as a physical intercept survey and may not be susceptible to some of the biases mentioned above, having the ability to electronically administer a survey to known system users mean data collection can be done more cheaply and more frequently than a physical version.

The rise in usage of this technology undoubtedly raises privacy concerns that must be addressed before some of these more invasive procedures could become the standard. But like with previous technological innovations, these concerns will in time subside: “each step in enhancing travel demand models leads to requirements for more data, not only a larger quantity of data, but also more kinds of data that include greater levels of intimacy” (PBQD, 2000, 3-26).

Another issue in data collection of bicycles versus PBS is the scale through which these systems have traditionally been planned. Bicycles have not typically been examined in a regional transportation planning perspective, but instead as a part of a human scale, or the Micro-Scale Design (PBQD, 2000). Although PBS are structured in such a way as to encourage short distance trips around a neighborhood, the discussion above shows their potential to be implemented across an entire transit region to better facilitate NMT trips in the suburbs and a Central Business District, connecting public transit’s first and last mile (Martens, 2007). For this reason, data needs to be collected on a similar scale to data collection on accessing other modes of public transit.

This chapter began to answer RQ1 by looking at criteria and indicators of other types of sustainable transportation systems as well as RQ3 in discussing the benefits sustainable transportation can add to a city's transportation system as well as RQ2A discussing what methods are being taken to collect data on such systems. Looking at Barcelona and Hangzhou answered what methods have been employed internationally to collect data on PBS (RQ2B) as The international case studies also partially answered RQ6, showing that there are currently PBS collecting data to provide support for claims of public health benefits.

The next chapter will finish the discussion of what are criteria and indicators of sustainable public bicycle system (RQ1). Identifying these criteria and indicators will aid in answering the questions which are concerned with what impacts a PBS have on a transportation system (RQ3) and the triple bottom line: are systems attempting to increase social equity (RQ4), do PBS generate economic development (RQ5) and are domestic PBS having an impact on public health (RQ6).

CHAPTER 3: INDICATORS

This section explains the criteria of a sustainable public bicycle system and indicators of such criteria that have been identified for the purposes of this thesis, see Table 3. The discussion of RQ1 from the previous chapter will be built upon to identify what indicators are required of a sustainable public bicycle system. Through identifying criteria and their indicators, the research questions concerned with sustainability's triple bottom line (RQ3, RQ4, RQ5 and RQ6) will be partially answered.

Table 7: Indicators of a Sustainable Public Bicycle System

Aspect of Sustainability	Criteria	Indicator
Economic	Economic Independence	Is the system generating revenue, or is it largely supported public funds?
	Jobs	Has the system created jobs?
	Economic Development	Are businesses around the PBS seeing an increase in revenue?
Social	Equitable Mobility	Does the system provide access to individuals across the region?
	Affordability	Does the system make accommodations for lower income residents?
	Public Health	Does the system encourage active transportation in its region?
	Safety	Does the system make cycling safe for both PBS users as well as urban cyclists in general?
Environmental	Resource Use	Does the system make use of renewable resources
	Emissions	Are there Green House Gas emissions produced by the system?
	Mode Replacement	Does the system make it convenient for users to switch from their traditional mode?
	Transit Integration	Does the PBS make regional non-automobile transportation easier?

Source: Gotschi & Mills, 2008; Gudmundsson, 2003; Hardy, 2011; Litman, 2007, 2011; Zietsman et al., 2011

Indicators of a sustainable public bicycle system are measured by the triple bottom line: economic, social, and environmental issues. The economic criteria show if a system is not only able to survive with little or no outside financial support, but also if it creates a net gain in the

economic structure of the region in which it operates. For this reason, the criteria of an economically sustainable public bicycle system are identified as revenue generation, job creation and the economic development the systems have on businesses around the stations. In addition to these, a system should be run efficiently in a matter to ensure that the greatest amount of operating bicycles possible are available at all times and distributed at stations where the demand is greatest. An economically sustainable system would be one that is fully funded through user-generated revenue, increases economic development in areas around the stations and along bike routes, and jobs the system creates.³

In order for a public bicycle system to be identified as socially sustainable, it must meet criteria that are concerned with impacts on both the system's users as well as non-users that reside in the system's service area. The indicators of such criteria are a system's ease of accessibility, the role a system plays in creating an equitable regional transportation system, how affordable is the cost of use, impact on public health, and the level of safety provided for both PBS members as well as other urban cyclists.

Environmental indicators are perhaps the most important in identifying a sustainable transportation system, as negative impacts from conventional transportation modes may be most apparent in this category. Because of this, a sustainable public bicycle system should create a reduction in air and noise pollution, as well as consuming a minimal amount of natural resources. Aside from direct impacts on the natural world, environmental indicators of a sustainable PBS examine travel mobility; is the system decreasing vehicle miles traveled through encouraging mode replacement? Is the public bicycle system integrated with a city's public transportation system? Has the city seen a reduction in levels of congestion since the

³ Some economic and social indicators such as public health and economic development are difficult to measure. The Findings chapter of this thesis provides a discussion on what potential methods can be undertaken to identify these indicators.

system has been implemented? Each of these questions should be answered with a 'yes' in order to be identified as a sustainable transportation system.

It should be mentioned that each indicator is not mutually exclusive to any branch of the triple bottom line, which it has been mentioned under (Hardy, 2011; Litman, 2007, 2011). For example, 'equitable mobility' is listed as a social indicator, but it can be also considered as an indicator of economic sustainability as a system that has too costly membership fees will not offer equitable access to all residents.

Also, transit integration and equitable mobility are listed under different categories, as two separate indicators although they should be considered similar. These were kept separate because a system that has transit integration may offer more equitable mobility, but it will also have environmental benefits. Also a system that offers equitable mobility options need not necessarily be integrated with public transit.

Some researchers (Litman, 2007, 2011) have suggested that a socially sustainable transportation system ensures community development. Although this is not mentioned specifically as an indicator for the purposes of this thesis, and the social indicators mentioned above focus predominately on impacts to system members, it is still important to examine how the general population is effected by the system.

To examine community involvement there are certain indicators, while not specifically designed to measure this criterion, can suggest how much the system is impacting the community at large. For example, a public bicycle system that increases equity on the regional scale should work with residents to determine where new stations should be placed. Also, in examining some of the environmental indicators (such as congestion impacts or noise pollution) impacts to the larger community can be seen. Likewise, if the system does create new cyclists who ride in neighborhoods that are typically void of bicyclists, this could lead to an increased

level of noise pollution. While the existence of certain negative externalities does not disqualify a system from being identified as sustainable, the most sustainable systems will ensure that there are minimal, negative externalities.

Vehicle Miles Travelled (VMT) is certainly one indicator of a sustainable transportation system, with a lower number being more favorable. However, should a system strive for such a high reduction in VMT that it decreases accessibility for residents who are dependent upon private automobiles for economic purposes (i.e. live in urban center, work in suburbs and no PT is available), it cannot be thought of as sustainable. Ideally, a reduction in VMT would happen in conjunction with an increase in mobility and accessibility for residents (Handy, 2002; Litman, 2012). Only by looking at VMT in relation to the types of trips being made and if a trip would have been taken had the PBS not been an option so as to measure impacts on accessibility and mobility, should a reduction of VMT be thought of as favorable.

By examining crash data, user perception, and mode share of traditional urban bicyclists, safety can be determined. More cyclists on the road (both PBS and non-PBS bicycles) indicate a general level of safety (Jacobsen, 2003).⁴ While a safe system is beneficial to public health, there are other considerations in determining what benefits the PBS offers public health. For this criterion, data on average trip length (time and distance) and air pollution in a city will be examined.

It should be noted that the presence of any or all of these criteria does not mean a system is sustainable. At the same time a system that possesses all the above-mentioned criteria, but sees very low usage rates, should not be considered unsustainable, but rather less sustainable than desired.

⁴ See the discussion of Jacobsen, 2003 and “safety in numbers” discussion in previous chapter.

This chapter has served predominately to answer RQ1: what are key criteria of a sustainable public bicycle system and the indicators of such criteria. In addition it has outlined the types of benefits a sustainable public bicycle system should offer a transportation system, as concerned with RQ 3, RQ4, RQ5 and RQ6. All of these prepare for the next chapter, which will examine what data collection methods existing public bicycle systems are using, and what indicators are being seen.

CHAPTER 4: CASE STUDIES

This chapter will serve to answer the research questions regarding exactly what attempts three of the oldest domestic public bicycle system are making to collect data and which indicators discussed in the previous chapter, present themselves through this data collection. In some cases systems are collecting data, which allows measurement of criteria for sustainability, but have not stated the primary concern of these efforts as being related to sustainability. The data in this chapter comes from past studies on the individual stems discussed, interviews with people who are associated with the data collection efforts of the systems, as well as some original surveys the systems have conducted themselves. This chapter will address all research questions except for RQ2A, which focuses on international systems.

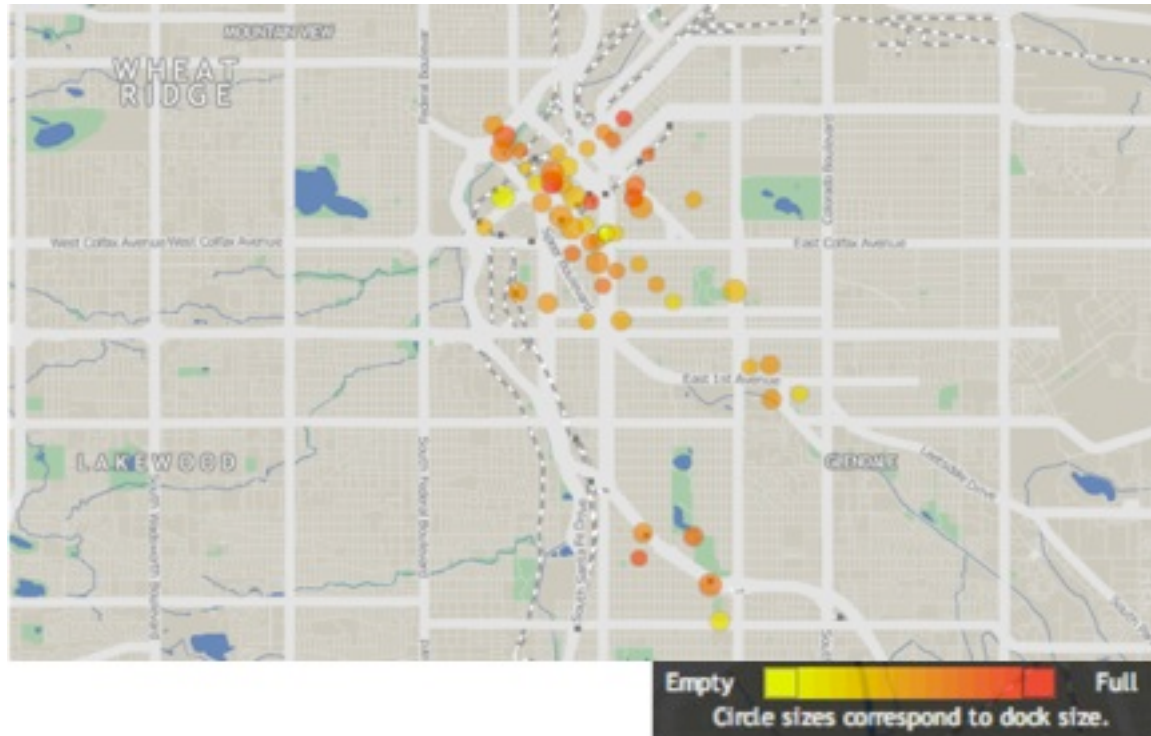
PUBLIC BICYCLE SYSTEMS IN THE UNITED STATES

Third Generation Public Bicycles are only now beginning to develop in North American cities. The first, and currently largest system began in 2009 in Montreal, Canada. As of March 2012 systems are operating, or in some stage of planning in over 30 North American cities. The three systems examined for this thesis are Denver, Colorado's B-Cycle, Minneapolis, Minnesota's Nice Ride-MN, and Washington D.C. and Arlington, Virginia's Capital Bikeshare (CaBi). These three systems were some of the first to begin service in the United States and each has a different operation model. In addition to being pioneers in PBS, these three regions have all made significant investments in non-motorized transportation through multi-use trails and on street bicycle facilities. Each of the three also rank among the top 15 biking and walking commuting shares in the United States, a ranking which predates the introduction of their respective PBS (Swanson, 2012). This chapter is divided into two parts; the first provides a brief description of the bicycle infrastructure of each city before and after the PBS was introduced as

well as an overview of the systems and their data collection techniques. The second half analyses the data that has been collected and how this information relates to the indicators identified in the previous chapter (Table 3).

Denver B-Cycle, Denver, Colorado

Figure 10: Denver B-Cycle Stations



Source: O'Brien, 2012a

The smallest of the three US case studies examined here, Denver uses the B-Cycle public bicycle system, created through a partnership of the advertising firm Crispin Porter + Bogusky, Humana Healthcare and Trek Bicycles. Launching in 2010, this was the first city to purchase the B-Cycle system, which is now used by 14 other cities nationwide (B-Cycle, 2012). This early adoption of the technology has meant the program serves as a trial ground for discovering what does and doesn't work both in terms of the physical bicycles as well as the back end software and membership management (Bohnenkamp, 2012). This system relies heavily on the information technology described above and makes particular use of GPS

tracking, offering members the ability to see an exact number of miles traveled as well as a simple calculation for calories burned and CO₂ reduced.

Prior to the development of Denver B-Cycle, the city offered a temporary first generation PBS system during the 2008 Democratic National Convention, known as *Freewheelin* (Bohnenkamp, 2012). Operated as a joint venture between the advertising firm Crispin Porter + Bogusky, Humana Healthcare, and Trek Bicycles, the program offered seven staffed stations throughout the city where people could come pick up and drop off bikes and saw over 5,500 trips made covering greater than 26,000 miles during the convention (Denver B-Cycle, 2012). After the convention concluded, the host committee donated \$1,000,000 to the city to help launch such a program after the convention concluded (Denver B-Cycle, 2012). During this time Crispin Porter + Bogusky, Humana and Trek made their one time partnership into a more permanent venture, launching B-Cycle and Denver Bike Sharing, a 501(c)(3) non-profit, began operating the B-Cycle equipment in April 2010 (Bohnenkamp, 2012).

Since the initial investment from the Democratic National Convention's host committee, Denver Bike Sharing has been awarded a Funding Advancement for Surface Transportation and Economic Recovery (FASTER) grant through the Colorado Department of Transportation (CDOT) as well as a Transportation, Community, and System Preservation (TCSP) grant through the Federal Highway Administration (Bohnenkamp, 2012). The grants serve to fund system expansion while revenues from memberships and usage fees cover close to half the system's operating costs while an additional \$530,000 in sponsorships make up the other half, resulting in an annual operating cost of between \$1-1.2 Million (Bohnenkamp, 2012).

The main data source for examining the systems operations and guiding the future efforts of Denver Bike Sharing come from user surveys in 2010 and 2011. These studies have been conducted by a board member who is also currently a Ph.D. candidate, researching public

health benefits of the PBS.⁵ The methodology for these surveys involved direct mailings to all members.

Integration between Denver B-Cycle and the Denver public transit agency, the Regional Transportation District (RTD), is in a community partner type model focused primarily on securing funding, and allocating space for the PBS at transit hubs. Denver Bike Sharing is working with the RTD to ensure the current expansion to its light rail network features design considerations for PBS docks in addition to advocating for more transit oriented developments that connect to the bicycle network. Future goals do include making the system into more of a 4th Generation PBS, with a single fare card to access both the bicycles and public transit modes. However implementation of this level of synergy of modes is still in the distant future (Bohnenkamp, 2012). The transit agency also helps in securing federal funding (such as the Congestion Mitigation and Air Quality Improvement Program, CMAQ) as Denver Bike Sharing is not a public agency and therefore not able to apply for these funds on their own.

In 2011 the Denver B-Cycle system launched a pilot program to increase the system's equity and accessibility in the region by focusing on the cost of the membership and required credit card as payment method to deter theft and vandalism to the system. Through a partnership with the Denver Housing Authority and a grant from LiveWell Colorado, Denver Bike Share identified potential users who lived in affordable housing developments that were located adjacent to PBS stations. The 800-900 people targeted in these developments were offered subsidized annual memberships, reducing the rate from \$65 to \$15 a year. The grant from Live Well Colorado provided the funds to cover the usage fees for low income users as well as the finances covering the liability of the bicycles, should anything happen to them for which a credit card is required of conventional users. The pilot program resulted in 35 residents of the target

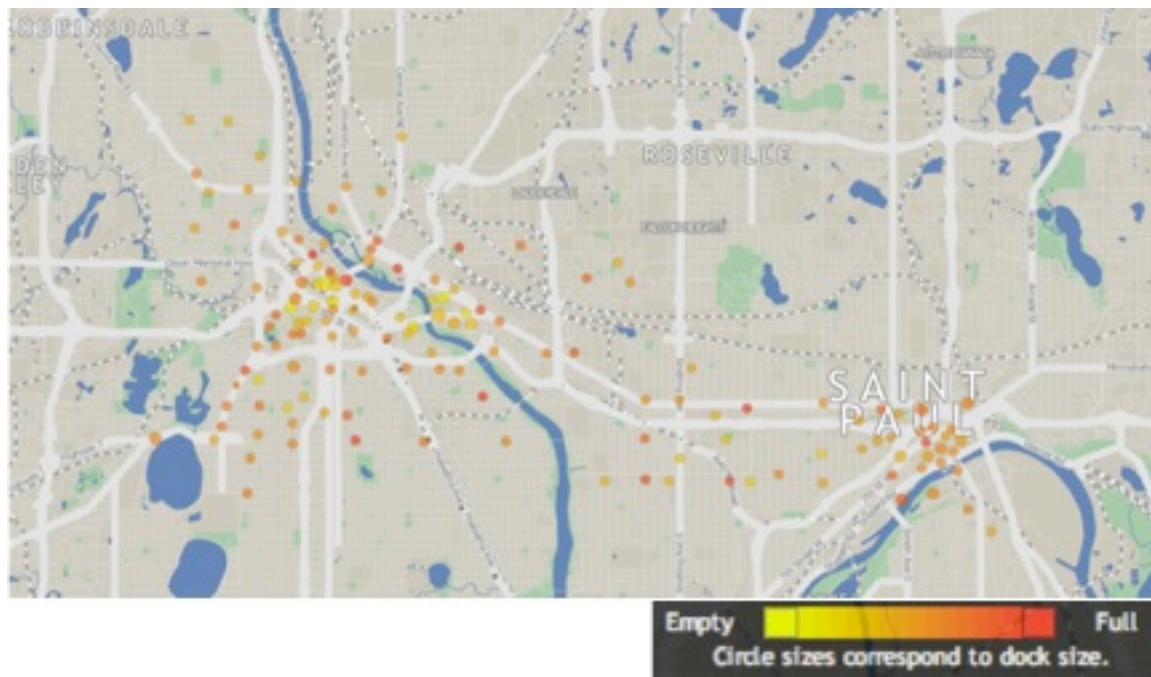
⁵ No data in regards to specific questions asked and methodology undertaken by this researcher is included in this research. Due to his work being unpublished and currently under analysis, I was unable to secure permission for use.

population taking advantage of the discounted membership, less than ten of whom became regular users of the system (Bohnenkamp, 2012).

With each user needing a unique ID to access the system, B-Cycle systems offer users an online dashboard to view how many calories they have burned, total miles traveled, and an estimation of CO₂ offset, which is based off a formula Denver Bike Sharing has developed (Bohnenkamp, 2012).

NICE RIDE, MINNEAPOLIS, MN

Figure 11: Nice Ride Stations



Source: O'Brien, 2012b

Arriving on the heels of Denver B-Cycle's April 2010 launch, June saw Minneapolis introduce their own PBS, Nice Ride. This system was considerably larger than Denver's at the time of launch, with 700 bikes and 65 stations resulting in over 100,000 trips in its first year (Nice Ride, 2010b). Nice Ride operates seasonally, like Denver's B-cycle, shutting down during the winter months to prevent damage to the system from the harsh weather, as well as meeting

a decline in the number of users. Minneapolis has a well-established network of on and off street bicycle facilities, which have been well researched and discussed in the Literature Review chapter of this thesis.

Another similarity the Minneapolis system shares with Denver is the operating model; the non-profit Nice Ride was created for the sole purpose of operating the city's program. This non-profit operator model was chosen somewhat out of necessity, as there were no for-profit operators currently available in the United States and the city did not want to operate it themselves (Dossett, 2011). The system is funded through a variety of both public and private sources including major contributions from Target (a Minneapolis based company), \$1 million of a tobacco settlement case through Blue Cross Blue Shield of Minnesota, as well as a small amount from the city itself. Nice Ride has gained strong support from the City of Minneapolis which assists in securing federal grants, and the PBS in turn uses any profit made to promote bicycling and walking in the city (Dossett, 2011).

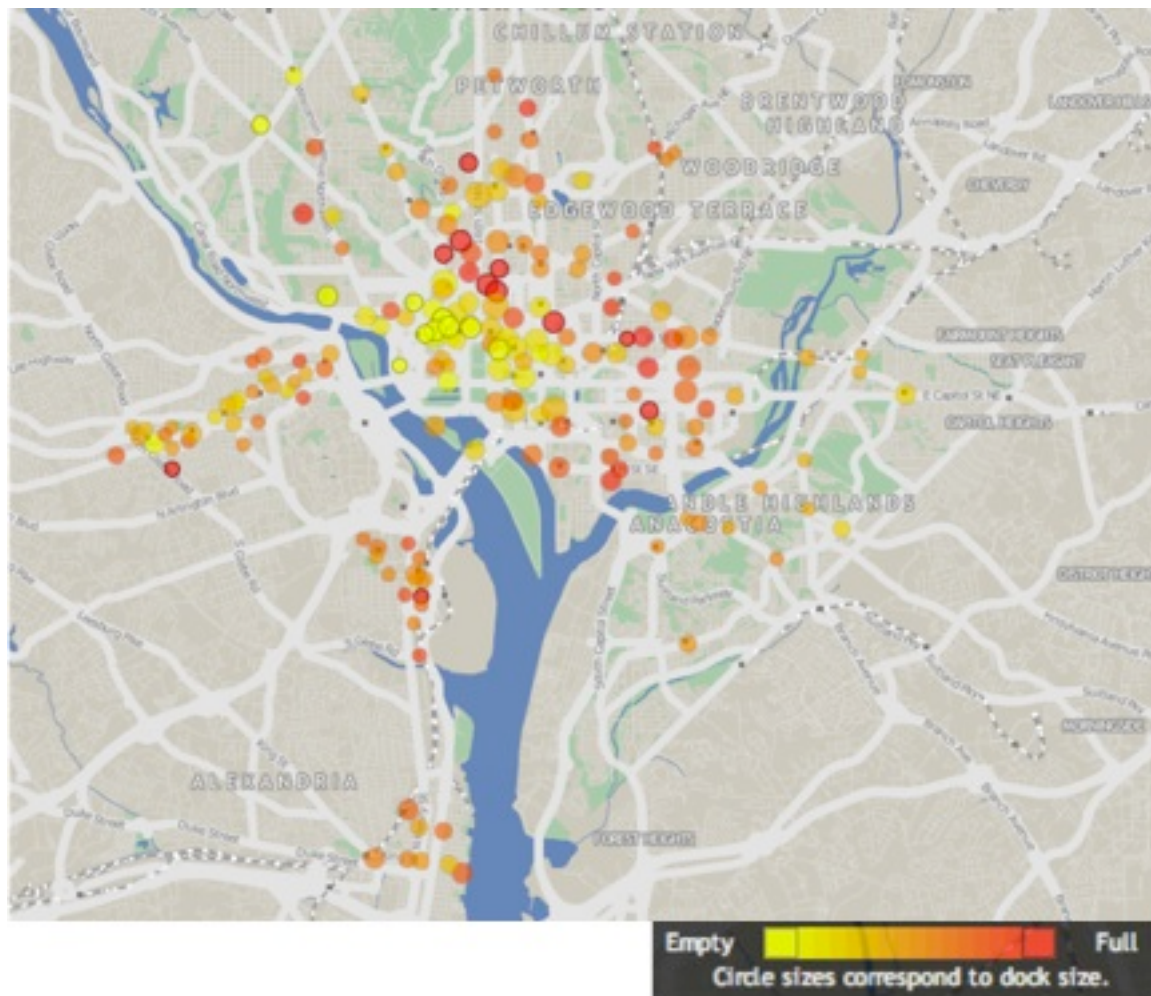
At the end of their first two seasons, the system has conducted a survey of users to measure what types of trips are being made, potential mode replacement, and approval of the way the system is run. Nice Ride publishes findings of their annual reports by removing all personal identifiers of respondents (Dossett, 2011). The surveys are distributed via a link emailed to members; no data is currently gathered via physically intercepting system users (Dossett, 2011).

While other similarities between Nice Ride and Denver Bike Sharing have been mentioned, a major difference between the two programs is the hardware the two cities use. Instead of going with the Trek/Human B-Cycle bikes, Minneapolis chose to partner with Public Bike System Company, which had seen success serving as the bikes in Montreal's PBS, BIXI (Dossett, 2011). Although GPS can provide more detailed data on trips being made with the

PBS, Nice Ride has not built it into their system nor has any plans to add it in the future (Dossett, 2011; Stopher & Speisser, 2011; Schneider et al., 2005). This thought behind this decision appears to have little to do with data collection but rather when the system was launched GPS was thought of primarily as a vandalism deterrent and the \$100,000 cost to add the technology did not seem wise compared to the estimated \$10,000 it could save (Dossett, 2011).

CAPITAL BIKESHARE, WASHINGTON, D.C./ARLINGTON, VA

Figure 12: Capital Bikeshare Stations



Source: O'Brien, 2012c

Capital Bikeshare (CaBi) is unique from the other two case studies as it operates on the regional scale, beginning a partnership between Washington, D.C. and Arlington, VA in the summer of 2010. This system collects a large amount of data on its impacts of their 165 stations, 1,500 bicycles and ~18,000 annual and monthly members and has strived to make their information public (D-DOT, 2012; LDA Consulting, 2012a). Although this system has seen success on this regional scale and has plans for further expansion into Virginia and Maryland, this thesis will primarily look at the partnership between Washington, D.C.'s Department of Transportation (D-DOT) and Alta Bicycle Share

The capital city's first attempted PBS was done as a partnership between the District Department of Transportation and the international advertising firm Clear Channel. At the time, this partnership came naturally as D-DOT already has a contract with Clear Channel to sell advertising on the district buses and bus shelter and the advertising firm itself has a PBS system of their own (SmartBike) already in operation in Europe (Lisle, 2011). The venture only saw moderate success, as the capacity the system could offer did not meet the demand of the community.

To meet the larger than anticipated demand, the district went back to the drawing board, issuing a new request for proposal (RFP). Through an agreement between local governments in the region, when one municipality issues an RFP, others are allowed to attach themselves to the program; this was the process that allowed Arlington, VA to become a partner in the program. The contract was awarded to Alta Bicycle Share, a subsidiary of the urban planning firm Alta Planning. This was the first city to adopt the Alta Bicycle Share operator model, a private company which controls all operations and maintenance for D-DOT, although unlike B-Cycle, the hardware is made by a third party.

Data collection on the impacts of the system has been done through a variety of methods. The system itself collects basic origin-destination data, using RFID readers, and not GPS. D-DOT has also conducted an annual user survey of the two years, during which they have been operational. These surveys have examined the impacts the systems have had on annual and monthly members transportation mode choice, how much more likely members were to visit a restaurant or business adjacent to a Capital Bikeshare station, integration of Metrobus and Metrorail with CaBi trips, vehicle ownership levels of members, helmet usage when riding CaBi, operational oriented questions regarding desired improvements and basic socio-demographic questions (Moskowitz, 2012). Through an easy to use public dashboard, D-DOT provides easy access to system data through four key metrics: Ridership, Membership, Customer Service, and Fleet Performance and Safety (D-DOT, 2012b).

The 2011 user survey distributed electronically to the system's 18,000 annual and monthly members asked a total possible 63 questions, although some were conditional based upon a user's previous response while other questions had the option for multiple responses, and saw a 31% response rate (LDA Consulting, 2012b; Moskowitz, 2011). As Capital Bikeshare has seen a great number of memberships and annual trips made soon after its inception, to ensure they are offering the best possible service as they work out the kinks, the annual surveys have been very much operations focused (Moskowitz, 2012). Although the study was neither commissioned by, nor collected for Capital Bikeshare, the CaBi system has some of the most comprehensive data regarding casual users (users without a monthly or annual membership) of any PBS in the United States. Researchers at Virginia Polytechnic Institute performed an intercept survey asking casual users questions similar to those in the CaBi annual user survey (Virginia Tech, 2011).

Although all the systems used as case studies have stated some level of commitment to make the systems more accessible to lower income residents, CaBi has launched a pilot

program to not only create a more sustainable transportation system, but also increase social equity within the region. Through a partnership with Bank on DC, an organization that works to help disenfranchised residents open bank accounts and get credit cards, Capital Bikeshare is offering reduced memberships for new and existing customers of Bank on DC (D-DOT, 2012a). The fundamental difference between this and the similar program in Denver is this is directed at including everyone in the program by providing credit cards for all economic groups, as opposed to a grant that would offset any potential theft or vandalism (D-DOT, 2012a). As this program is still in an early testing phase, data has not been made available on its positive or negative impacts. Should this effort be successful, it could become a model other systems could recreate.

FINDINGS

Of the three systems examined data collection is occurring at each in some level, although the intention does not appear to be measuring sustainability, see Table 4. Instead each of these systems currently appear focused on gathering data in regards to examining user's perception of how well the systems are functioning as opposed to their sustainability and the overall impact they are having on the transportation system. As the systems become more established in a transportation system, and work out their initial kinks they appear to begin to turn their attention more directly toward sustainability. However, while the intention may not be sustainability verification, many of the variables the systems are measuring, could present indicators of sustainable criteria. For example, in trying to determine whether or not stations are placed in the best locations, a surveyor may ask a business located adjacent to a station whether or not they have seen increased revenue since the station's launch. This would show both if the station is well placed and if the system is spurring economic development, although one is not dependent on the other. Below is a discussion of this thesis' findings of the systems'

data collection and what it could mean for ensuring a sustainable transportation system in the future.

As Table 4 shows, the systems are collecting data on a variety of topics, some of which are criteria for a sustainable public bicycle system. The types of questions asked are clearly intended to give the system operators an idea of what their users are using the system for, as well as areas where they could improve service. This approach is indirectly measuring criteria for a sustainable public bicycle system, with questions directly asking users about all criteria, except for environmental impacts and equitable mobility. It should be noted that although Denver was not represented in Table [...] as the specific questions they asked were unavailable, their annual surveys measure to some degree each of type of question listed in the table (Bohnenkamp, 2012).

While each case study city has a slightly different operator model (non-profit, for profit/transportation agency) there does not appear to be a clear variation between data gathering techniques, suggesting that one model is no more conducive to measuring sustainability than another.

Although no quantitative data is available on the effect it has had, Capital Bikeshare has taken steps to increase public participation, an indicator of a sustainable system. As mentioned above, CaBi is planning an expansion with more stations in both D.C., and Virginia, and spreading into Maryland. In choosing the locations of these stations residents were able to go online and vote for potential locations in addition to voicing concerns at numerous public hearings (D-DOT, 2011b).

Table 8: Current Data Collection for Public Bicycle Systems in Minneapolis, MN and Washington, D.C.

TYPES OF QUESTIONS ASKED	SYSTEM		
	Nice Ride, MN Annual User Survey (2011)	Capital Bikeshare Annual User Survey (2011)	Capital Bikeshare Casual User Survey (2011)
Mode replacement	6	2	--
Approval of operation of system	8	21	11
Integration with other modes	17+	13+	1+
General bicycle use characteristics	1	1	1
Environment	~	--	--
Demographics	9	9	5
General trip data	8	13	6+
Health/Safety	2~	4	1~
Economic	~	9	~
Equity	--	--	--
~One or more questions, while not asking about these			
+One or more questions counted in this category asked			
# An unknown number of questions were asked on this			

Source: Dossett, 2011; LDA Consulting, 2012; Moskowitz, 2011, 2012; Virginia Tech, 2011

One of the most interesting findings in the comparative study of Capital Bikeshare casual and annual members, was gender divide. The majority of urban bicyclists in the United States are male, with the 2010 Census finding this to be true of 75% of bicycle commuters in the District of Columbia and 67% of urban cyclists in the United States as a whole (Virginia Tech, 2011; US Census, 2011). In spite of this gender divide typically favoring men, study of casual users found 52% of the 340 casual users were female compared to the only 33% of annual

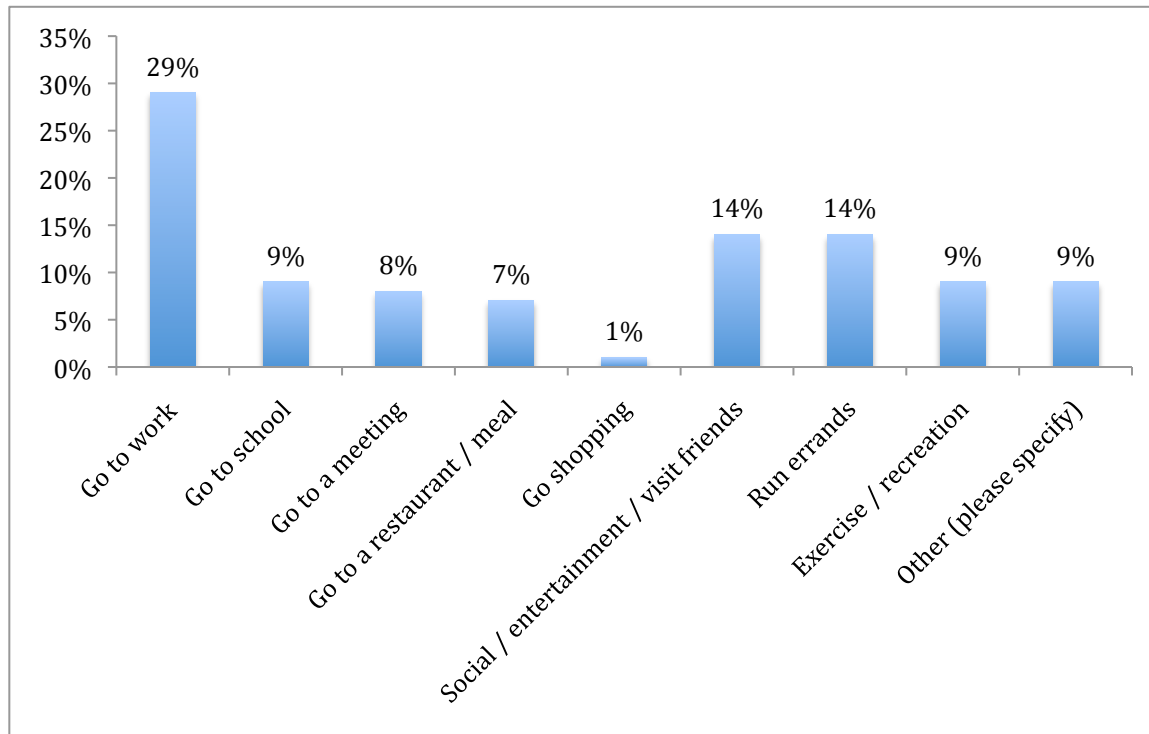
CaBi members that are female (Virginia Tech, 2011). One qualification of this finding was the study only counted the gender of those users who responded and not all users who came to a particular station, thus this figure could be more telling of the gender of respondents as opposed to actual casual users (Virginia Tech, 2011). Either way this suggests the need for greater address the gender divide among public bicycle system users.

Capital Bikeshare's member survey provides perhaps one of the most direct connections to validate claims of PBS offering a more sustainable mode, specifically through reducing vehicle miles travelled. The survey shows that although the PBS did induce trips that users would not have made without the system, self-reported annual miles driven in automobiles before and after joining the PBS, show users reduced annual VMT by an average of 523 miles (LDA Consulting, 2012). In the case of Nice Ride, surveys showed the single most common trip made with the system was to commute to work and the mode replacement for such trips predominately came from walking, see Figures 5 and 6 (Dossett, 2012). The particular wording of the question should be noted: choose, "all modes that you would use during a single trip before bikesharing" (Dossett, 2012). Because of this, although 55% of respondents said walking was a component of the previous trip, still significant are the 40% of trips replaced from bus and 37% from single occupant vehicles.

Despite varying levels of integration between each of these three public bicycle systems and their region's public transit, they all express a desire to work with their public transit agencies to promote a multimodal transit system and use PBS as a way to address the first mile/last mile phenomenon as discussed above (Bachand-Marleau et al., 2010). Although it is not shown in the data being collected, further integration does appear to be imminent with the primary hindrance being the relative youth of each system and in time they would like to make the transition to a single fare card to access each mode (Bohnenkamp, 2012; Dossett, 2011;

Moskowitz, 2012; Witte, 2011). In spite of the lack of integration, users have already begun integrating PT into their trips, see Figures 7 and 8 (Dossett, 2012).

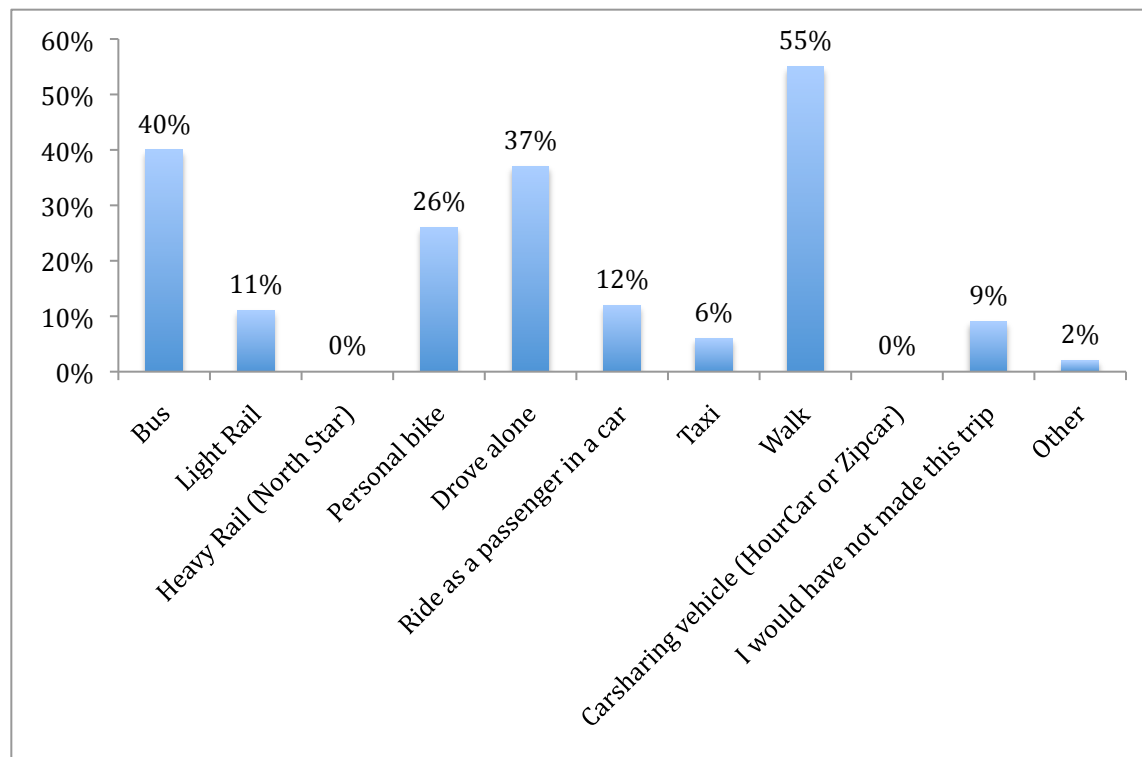
Figure 13: What is your most common trip purpose?



Source: Nice Ride 2011 User Survey (Dossett, 2012)

Denver does appear to be collecting the appropriate data to identify sustainable indicators. However, due to proprietary data, as discussed above, this thesis is unable to breakdown the exact type of questions the system is asking its users in and compare with the other two case study cities. Bohnenkamp (2012) and data the system has reported in their annual report both provide an overview of the types of data being collected which are similar to that of the other two systems (types of trips, socio-demographic data, vehicle ownership, etc.) which suggests data is being collected which could verify the sustainability of the system.

Figure 14: Before Nice Ride Minnesota was available, how would you have made this trip most often? (Select all modes that you would use during a single trip before bikesharing.)



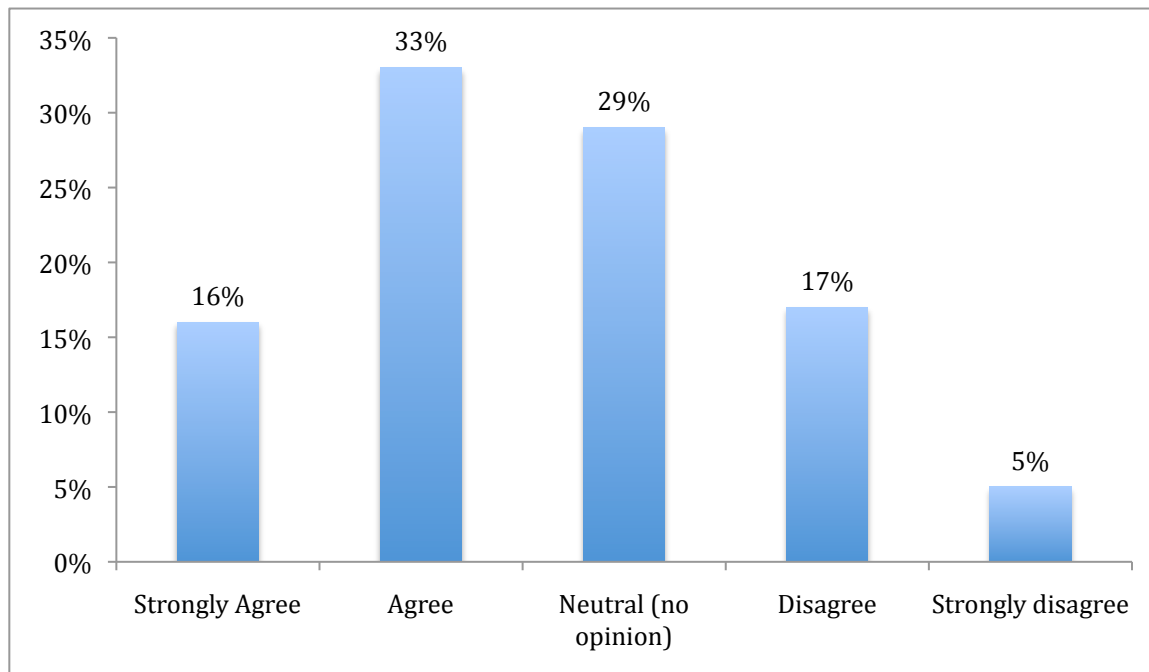
Source: 1Nice Ride 2011 User Survey (Dossett, 2012).

One particular indicator that can be seen by simply looking at a map is the level of transit integration. As the Denver Bike Sharing matures there are plans for integration of a common fare card between public transit and PBS, but for now the primary focus interaction between the two modes proximity of bicycle docks to major transit hubs. Being a non-profit makes Denver Bike Sharing ineligible to apply for certain grants which means and therefore must work alongside the regional transit agency. This also ensures the two groups will work on planning future expansion and integration together.

Nice Ride is very similar to Denver in this relationship between PBS and PT provider. Looking at funding sources, the system does appear to be more on the economically sustainable side, moving away from public sources which helped launch the program and

instead covering costs using the revenue they generate from memberships and their private sponsors (Dossett, 2011).

Figure 15: As a result of the availability of Nice Ride Minnesota, I consider using public transit more often.



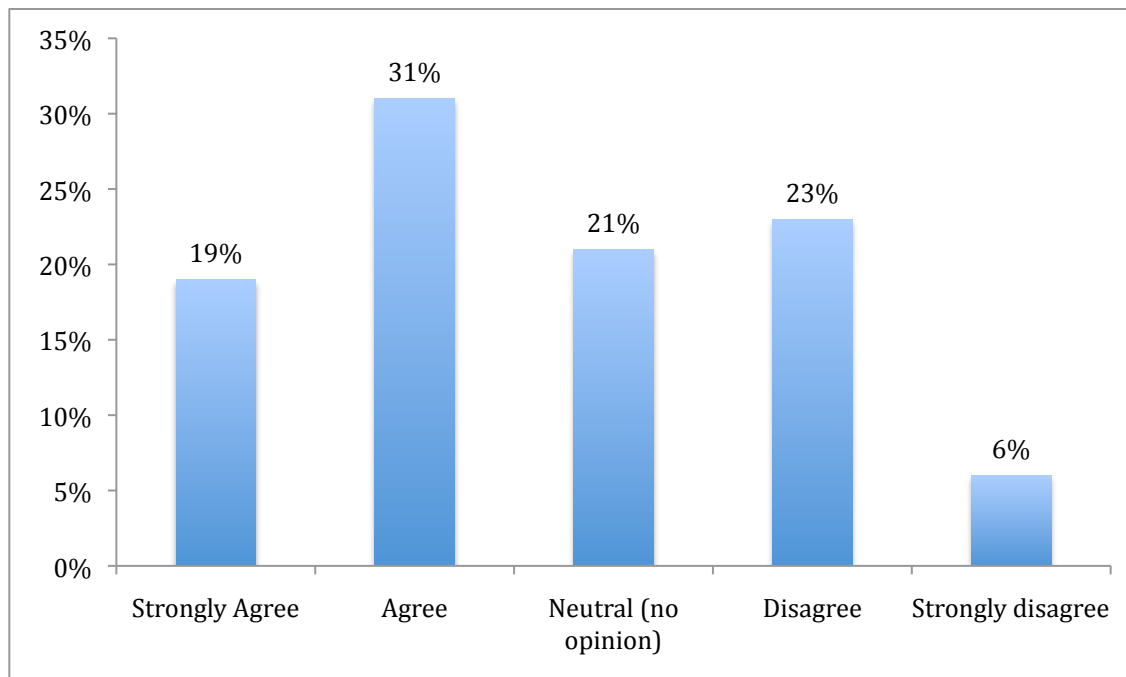
Source: Nice Ride 2011 User Survey (Dossett, 2012).

The system does collect data and meets many of the indicators of a sustainable transportation system. One area of particular concern to Nice Ride in their first year was providing equitable access to neighborhoods that would like PBS stations, but do not have the housing density, bicycle usage or retail destinations Nice Ride typically requires to support a station (Dossett, 2011). The result was partnering with community groups, offering discounts or developing bike tours in these areas (Dossett, 2011).

Pilot programs such as Denver's efforts to increase low income resident usage and CaBi's are an ideal method to test out a new approach at increasing a system's sustainability without having to modify the entire model of the system. It should be noted that these attempts at making the system more affordable for select groups, does not necessarily guarantee a more

sustainable system as it may prove to be an ineffective use of the system's revenue. The attempts discussed above are new and data on their impacts is still inconclusive (Bohnenkamp, 2012).

Figure 16: Since joining Nice Ride Minnesota I have made trips with transit and bikesharing (together) that I would have previously done with a car.



Source: Nice Ride 2011 User Survey (Dossett, 2012).

Although it was mentioned above that no system operator model appears to be more conducive to data gathering, there are certainly benefits one model has over another in determining how sustainable the service provided can be. The primary issue here is public accountability. For example, as both Nice Ride and Denver Bike Sharing are non-profit/non-governmental organizations (NGO), they are able to be more experimental in their approaches and more rapidly launch a pilot program, as they are not as tied to being responsive to the general public. It was through this kind of freedom that Denver was able to quickly launch their low-income resident program (Bohnenkamp, 2012).

Similarly public agencies typically have a process through which partnerships are made (i.e. RFPs) which means programs such as CaBi's partnering with Bank on DC, will certainly have a lengthy bureaucratic process to go through before the program can continue. While pilot programs may take longer to come to fruition in public agencies, this operator model has the advantage of being more influential on the transportation network of the region as a whole.

The most ideal model may be a hybrid one, which draws a little bit from all three case studies and forms a public/private partnership where both groups have a vested interest in the system's success. The private operator will be able to push the program's development, trying riskier projects while the public side will assure that all the necessary permits are cleared and can tie the system into the larger transportation network as well as accessing to funding sources out of reach from private organizations.

This chapter has used the indicators of a sustainable transportation system as identified as part of RQ1, to analyze what data PBS are collecting (RQ2), and thus highlighted a lack of standardization in data collection (RQ2A). The systems are collecting data on the types of trips being taken and modes being replaced (RQ3A and RQ3B, respectively), but there is no clear indication about the long-term effects the PBS will have on a city's overall transportation system. The attempts to increase social equity within a transportation system are still in early phases and thus data was not readily accessible to analyze the impacts of such efforts, therefore RQ4 was confirmed, while RQ4A was left inconclusive. Difficulties with finding a specific signs of economic development resulting from the PBS were discussed, leaving RQ5 without a concrete answer. Finally RQ6 was inconclusive as well. The only system that published data on some aspect of public health was Denver's B-Cycle who only put out a total number of calories burned; there was no attempt to quantify this number into greater public health impacts. The final chapter will build more upon these findings as well as recommend potential areas of further research.

CHAPTER 5: CONCLUSION

Based on the case studies of the public bicycle systems in Denver, Colorado, Minneapolis, Minnesota, and Washington, D.C., it is evident that the collection of data on impacts these systems are having is taking place. However the primary motivation of this data collection is to measure the whether or not the system is being operated in a manner that satisfies its customers. In spite of this, some of the topics the PBS are analyzing can show the existence of criteria for a sustainable transportation system (mode replacement, affordability of membership, trip distance, etc). The reason for this focus of data collection appears to be ensuring these still relatively young systems are being operated in a way that offers a service the public desires.

This chapter will serve to bring together the previous chapters and restate the findings of the research questions. Additionally this chapter discusses what future research on the topic should examine and finally the potential impacts this thesis can have on the field of public bicycle systems.

To summarize the results of the Research Questions posed in this thesis:

- **RQ1:** There are criteria and key indicators of such criteria for both a sustainable transportation system and sustainable public bicycle system. The criteria found to determine the level of sustainability a PBS is, were: economic independence, job creation, economic development, equitable mobility, affordability, public health, safety, natural resources used, emissions, mode replacement, and integration with public transit.

- **RQ2:** The data currently being collected on public bicycle systems is primarily concentrated on measuring the program's efficiency, user satisfaction, and types of trips being made. Sustainability is the focus of such data collection efforts.
 - **RQ2A:** The systems have standard data collection methods within themselves, but standardization does not carry between systems.
 - **RQ2B:** International systems have collected data through user intercept and stated preference surveys.
- **RQ3:** The data shows that PBS are becoming another mode available within a city's transportation system, longitudinal impacts are still unclear.
 - **RQ3A:** The data collected suggests the types of trips being taken are similar to those made in automobiles, non-work related trips.
 - **RQ3B:** The cities with data on mode replacement seem to be show impacts primarily on walking trips, although public transit and private automobile trips are being replaced as well.
- **RQ4:** The data collected shows attempts are being made to increase the social equity of transportation systems.
 - **RQ4A:** The efforts to increase equity are still in early stages and data is not conclusive, although the program in Denver saw much lower than desired number of subscribers from their target group.
- **RQ5:** The data collected suggests that there is potential economic development occurring as a result of the placement of PBS stations, although it is difficult to quantify a dollar amount. Most data collection has been along the lines of asking stores near stations if they have seen an increase amount of traffic since the program's launch.
- **RQ6:** The Barcelona example showed there are certainly health benefits from riding a public bicycle, but aside from a calorie count released from Denver B-Cycle, there does

not appear to be efforts to prove claims of public health benefits here in the United States.

Again it should be stated that the intention of this thesis has not been to identify which public bicycle systems in the United States are currently sustainable, but instead describe the criteria for a PBS to be considered sustainable PBS as well as highlight what efforts the three oldest U.S. PBS have been undertaking to gather data on indicators of such criteria. In other words the intent was not to confirm or deny sustainability within PBS, but rather examine whether or not these systems are even collecting the data, which could validate claims of PBS benefits.

DATA BEING COLLECTED

The systems provide a targeted population for which to conduct surveys and the data being collected must be used in conjunction with other surveys of the general population.

As the major data source analyzed in this thesis is the user survey, it is clear that this is the primary data collection method these systems are using, and it has provided valuable feedback on impacts the systems have been having as well as their overall performance. This is one major advantage public bicycles have over conventional bicycles as well as all other modes in an urban transportation system: a known user base who must provide contact information and therefore a direct line of communication for data collection.

Looking beyond only public bicycle users and instead conducting analysis at the community level can be beneficial in helping to answer questions relating to some of the indicators, that are not as easily measured. For example, measuring indicators of an economically sustainable system could be done by a survey of businesses around PBS stations, to see if there has been an increase in consumer spending. Even by looking beyond only users to attempt to analyze the impacts the system has on these more difficult to measure

indicators, the problem remains of trying to quantify the influence these systems are having. In the above example of surveying business owners, it is hard to put a dollar amount on the impact the systems have on economic development, aside from simply looking at total sales before and after the PBS came to the area, although there are certainly other variables which could explain any trend which appears.

The use of information technology has proven very beneficial in data collection. Analysis of the origin and destination of a trip in particular can now be more accurate than in any other mode, aside from using asking travelers to keep a travel diary, which has problems of its own. While some systems are only able to gather data of the specific origin and destination of a trip, others are using GPS that allows them to analyze the entire route of a trip. The inclusion of GPS should be something each system is undertaking in order to get the most accurate data, in spite of the high cost of such technology. As discussed in earlier chapters, construction of bicycle facilities can create more jobs than similar projects for private automobiles and at a lower cost (Garett-Peltier, 2010; 2011). For this reason, knowledge of the exact route decisions of a PBS user is extremely beneficial as it can highlight routes being taken which are currently underserved with appropriate bicycle facilities. The three case studies in this thesis do all have extensive on street facilities to accommodate urban bicyclists, but data showing this is required for a sustainable PBS is still lacking.

Despite the fact that these systems have not collected data specifically on sustainability, research for this thesis has suggested that PBS data collection will, in time become more sustainability focused. As bicycles are a cheap, healthy transportation option, which has no emissions, they are an inherently sustainable system, even PBS data collection that is not expressly focused on sustainability, measures some of the criteria discussed in the current system. Another potential indicator that these systems will begin further analysis into the sustainability of these systems is their stated commitment to sustainability in transportation as

all three regions have clearly defined sustainability goals. Looking further, into more recently developed or developing systems, a majority of systems have stated their goals of sustainability. While stating a desired outcome does not guarantee anything, it is at least a good start for these systems.

Public bicycle systems should also ensure they are operating in an open source style. Just as regional public transit systems across the country share their data between agencies as well as with the general public, PBS operators are not in competition with one another and the success of a system in one city can encourage use of a PBS in another. This open source data will also benefit users, as they are able to see how many bikes are at a specific station.

PILOT PROGRAMS

As discussed, the primary drive of Denver B-Cycle, Nice Ride, and Capital Bikeshare is not sustainability but to provide a system that is affordable and a viable option for their residents. Of the attempts that have been made to increase sustainability, the primary mode has been pilot programs; a small initiative that does not require an entire shift in the way the organization does business. One conclusion reached through researching this thesis is the need for more innovative data collection techniques. To address the difficulty in measuring many of the indicators of a sustainable system (economic development, public health) this thesis proposes that systems undertake a pilot program to get levels of data that are not currently being collected. Such a program would ask existing members to voluntarily provide personal data in the forms of travel diaries that show what kinds of trips are being made with the system as well as where people spend money while using the system. Although the systems do collect some of this data through their annual surveys, having a dedicated sample that will regularly provide feedback can give more quantitative data for these indicators as opposed to circumstantial. Furthermore, this sample population can be asked to come in for quarterly health screenings. This would benefit not only measuring the sustainability of a cities PBS, but also

many public health initiatives. All this type of study would certainly run into a self selection bias, this valuable, albeit skewed data source would be more beneficial than not having the data.

Privacy concerns over more invasive data collection discussed earlier in this thesis will be overcome as the pilot programs would be completely voluntarily and participants would be informed at the forefront what the data would be used for. One potential difficulty with acquiring this level of data would be the increased amount of analysis the systems would have to conduct, in departments that are not typically very large, or operating under a very strict budget.

Existing programs report that much of the economic development data comes from asking business owners near stations and along bicycle routes if they see a greater number of cyclists coming into their businesses resulting in data that is very circumstantial.

Nick Bohnenkamp of Denver Bike Share says they are looking at new analytical methods for the system but are currently focusing on ensuring the system is the best possible product for their users (Bohnenkamp, 2012).

Future Research

The effect public bicycles are having on North American cities is an area in dire need of more research. One example of such a gap are longitudinal studies, which have simply not been possible since even the oldest third generation system is less than a decade old (Shaheen, et al., 2009). This should be at the forefront of all efforts by cities wishing to start a PBS, for the longer they collect data on their system, the more beneficial the data will be.

Land use patterns are an indicator of sustainable transportation systems, which was not heavily discussed in this thesis. The primary reason for this is the historical disconnect between transportation and land use planning in the United States. Public bicycle systems in Western Europe and China have extremely high station density rates to accompany more dense

residential areas. Although some level of density is necessary since systems are designed to encourage short, one-way trips, more research is needed on land use patterns in the United States and to whether or not extreme density is necessary to have the most appealing system.

Although this is an aspect of PBS that certainly requires more research, other cities have seen improvements in PBS integration with regional transportation systems after they have switched away from advertising firms.

The most pressing area of research for public bicycle systems in the United States right now is how best to integrate fourth generation systems and what effect they will have. The case of Hangzhou (though a much larger scale) can serve as an example of integration between modes. But as the findings in the Hangzhou example show, more research is needed into the effects PBS has on public transit. Do transit levels remain the same after a PBS begins service? This would suggest that the trip replacement is not as extreme as it seems. It could however be opening up public transit as an option to people who before would have been deterred by the crowded vehicles and the trip replacement is coming from other modes, not PT and PBS.

With their roots in 1960s Europe, public bicycle systems are now gaining international appeal. In time many or all of the claims about the benefits public bicycles can offer North American transportation systems may be found to be true, the data is not currently there to support this.

Although the case studies represent only a small portion of the rapidly increasing number of public bicycle systems in the United States, the findings of this thesis do offer a valuable contribution to the ever-growing body of PBS related research. Public bicycles systems in the United States will continue to gain in popularity with cities like New York, Chicago, and San Francisco all announcing plans to create major public bicycle systems of their own.

This lack of empirical data regarding certain indicators of socially or economically sustainable systems should not deter cities from pursuing such systems. Instead cities wishing to start a sustainable PBS should look to efforts of existing programs including those case studies discussed in this paper. Any new system should put data collection at the front of their list of priorities to see what long-term impacts they are having on their region. Also systems should be an open source for data to help other programs see what does and does not work. This topic is also entirely relevant as bike shares continue to grow internationally and if not done in a means to actively change the urban transportation system, they can result in being seen as a novelty attraction in a city. In particular a sustainable public bicycle system in Asian cities in can have major impacts on cities that are seeing increasing motorization rates.

Increasing motorization rates across the world are really at the heart of ensuring PBS are sustainable. As urban areas across the world continue to grow, more private automobiles will mean more congestion thus an alternative is needed. Public transit will help in increasing mobility to these populations, but building rail is expensive and takes time, while a bus system will be fighting the same congestion as automobiles, unless given a dedicated right of way, which too is expensive. If PBS are proving to meet the criteria of a sustainable transportation system, requiring little financial commitment from the municipalities they operate in (beyond initial start-up costs), help relieve congestion on a small scale and have near-zero emissions, they should be considered as a must for every urban area to develop.

Although the United States has not been the leader globally in the development of public bicycle systems, there is now an opportunity to determine exactly what role they play in an urban transportation system. When New York City launches their PBS in 2013 with a planned 10,000 bikes, it has the possibility to increase the mobility of residents from all socio-economic backgrounds in what is one of the most diverse urban areas in the world. If their PBS is proven to be sustainable, it can show the rest of the world how to effectively launch such a system.

As the trend of developing public bicycle systems is part of a greater shift from conventional to sustainable modes and PBS themselves are an entirely new mode within the urban transportation system, this is an example of where theory and practice meet. In other words what may be described in this thesis and other literature describing what an ideal sustainable system would look like may not be a realistic expectation when actually putting the systems into practice, especially not at this early developmental stage. Because of this, measuring the sustainability of all modes of transportation, not only PBS, should be frequently revisited. A continuation of this thesis could use the indicators identified to construct a survey to analyze the impacts systems are having.

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Appendix A: IRB Exemption

***University Committee for the Protection
of Human Subjects in Research
University of New Orleans***

Campus Correspondence

Principal Investigator: John Renne
Co-Investigator: Max W. Williamson
Date: March 26, 2012
Protocol Title: "Measuring the Sustainability of U.S Public Bicycle Systems"
IRB#: 05Mar12

The IRB has deemed that the research and procedures described in this protocol application are exempt from federal regulations under 45 CFR 46.101 category 2b & 5, due to the fact that any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation. Research is conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine public benefit or service programs.

Exempt protocols do not have an expiration date; however, if there are any changes made to this protocol that may cause it to be no longer exempt from CFR 46, the IRB requires another standard application from the investigator(s) which should provide the same information that is in this application with changes that may have changed the exempt status.

If an adverse, unforeseen event occurs (e.g., physical, social, or emotional harm), you are required to inform the IRB as soon as possible after the event.

Best wishes on your project.
Sincerely,



Robert D. Laird, Ph.D., Chair
UNO Committee for the Protection of Human Subjects in Research

Vita

Max Williamson is graduate student of Urban and Regional Planning at the University of New Orleans (UNO). His Specialization is Transportation, with a focus on sustainable and non-motorized transportation. Born in St. Augustine, FL (the oldest continually inhabited European settlement in the United States) he has lived across the south and obtained his Bachelor's of Science in both Geography and Political Science from Florida State University in 2008. He was awarded a Dwight D. Eisenhower Fellowship from the US-Department of Transportation for his research on emerging trends in public bicycle systems. He currently resides in Austin, TX: live music capital of the world.